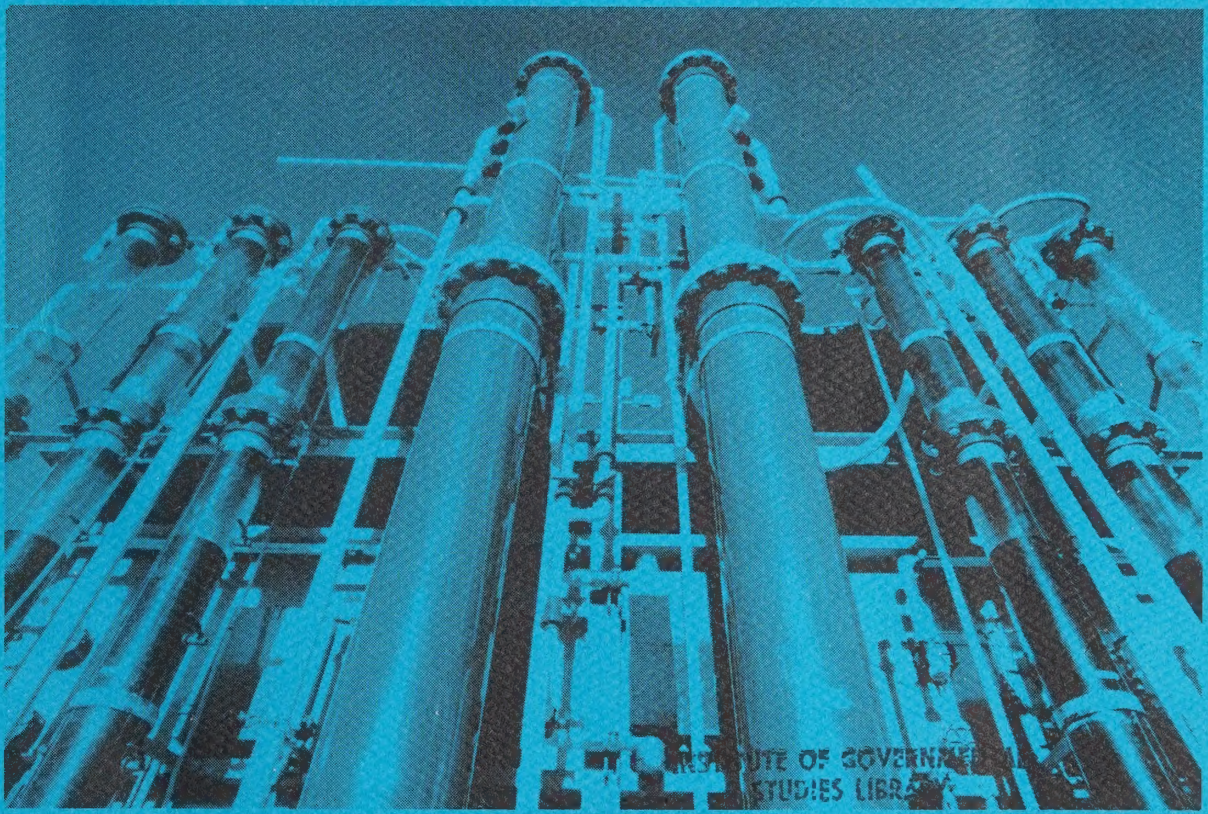
Case Studies of Industrial Water Conservation in the San Jose Area

February 1990



City of San Jose,
Brown and Caldwell Consultants &
Department of Water Resources

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EXECUTIVE SUMMARY

Many industries in the San Jose area save water by implementing cost-effective conservation measures. This report discusses 15 case studies of water-conserving companies, describing water uses, conservation measures, water savings, and economic benefits. The case studies centered around four industrial groups in the San Jose area--electronics manufacturing, metal finishing, paper reprocessing, and food processing. Combined water consumption of the case study companies was reduced more than 1 billion gallons per year by conservation measures. Economic benefits from the conservation measures resulted in a combined savings of about $2 million per year.

Water use by industrial manufacturers in Santa Clara County, where San Jose is located, averages 16 billion gallons of water annually. This is the fourth highest manufacturing water use rate of California counties. About 4 billion gallons per year are used by electric and electronics industries, mostly in the San Jose area. Other high water-use industries include food and kindred products, which use over 4 billion gallons annually.

Historically, water conservation has been a low priority for most industries because water is a relatively inexpensive cost item. In addition, a plentiful supply of fresh water is usually available. More recently, the concept of water conservation has gained prominence because of droughts and a heightened public awareness of the value of this strained resource.

Table I presents a matrix of case study companies and conservation measures. The companies are grouped by industrial category. The most common conservation measures are:

- Water use monitoring.
- Employee education.
- Recycling.
- Reuse.
- Cooling tower use.
- Equipment modification.
- Improved landscape irrigation.

Some companies adopted comprehensive conservation programs, while others focused on a few specific measures.

The case study results are summarized in Table II. The table shows:

- Each company's water conservation measures.
- Water savings in million gallons per year.
- Water savings in percent of preconservation use.
- Capital costs of water conservation measures.

- Annual monetary savings resulting from conservation.
- Payback period $= \dfrac{\text{capital costs}}{\text{annual savings}}$

For some companies, water use rates apply to total facility use; whereas, for others, only the use rates associated with a conservation measure are listed (for example, the water used for cooling). This is noted in the table. Similarly, the dollar savings may apply to a specific conservation measure or to the entire program, depending on the available economic information.

The cost-effective water conservation measures used by these companies could readily be applied to other industrial facilities. In the San Jose area and elsewhere in California, there is excellent potential to decrease the demand for one of industry's most valuable, yet limited, resources. The significant water use reductions and impressive cost savings shown in Table II demonstrate the benefits available to industries and water suppliers from water conservation.

Table I Water Conservation Measures at Case Study Companies

CONSERVATION MEASURE \ COMPANY	Electronics Manufacturing Industry										Metal Finishing Industry		Paper Reprocessing Industry		Food Processing Industry	
	Advanced Micro Devices	Exel	Hewlett-Packard	Intel	IBM	International Microelectronic Products	National Semiconductor	Spectra Diode Laboratories	Tandem Computers	Xerox	Dyna-Craft	Hi Density	California Paperboard Corporation	Container Corporation of America	Gangi Bros.	
MONITORING	●	●	●			●	●	●	●	●		●			●	
EMPLOYEE EDUCATION	●						●		●	●		●			●	
RECYCLING							●					●	●	●	●	
RECYCLING WITH ADVANCED TREATMENT			●													
REUSE		●	●		●	●	●		●				●		●	
COOLING TOWER (WATER RECIRCULATION)		●		●	●	●			●	●				●	●	
COOLING WATER OZONATION		●		●					●	●						
AIR COOLING								●								
EQUIPMENT MODIFICATION	●				●	●	●	●			●				●	
EQUIPMENT SELECTION														●		
PROCESS OPTIMIZATION	●	●													●	
CLOSED LOOP SYSTEM								●	●							
IMPROVED IRRIGATION	●	●			●		●	●	●	●						
LANDSCAPE MODIFICATION					●				●							
LOW-FLOW PLUMBING					●				●							

Table II Summary of Case Study Results

MEASURES AND RESULTS / COMPANY	Advanced Micro Devices	Exel	Hewlett- Packard	Intel	IBM	International Microelectronic Products	National Semiconductor	Spectra Diode Laboratories	Tandem Computers	Xerox
	Electronics Manufacturing Industry									
Conservation Measures	Monitor Education Equipment Optimization Irrigation	Monitor Reuse Cooling Tower Ozonation Optimization Irrigation	Monitor Recycling Reuse	Cooling Tower Ozonation	Reuse Cooling Tower Equipment Irrigation Landscape Plumbing	Monitor Reuse Cooling Tower Equipment	Monitor Education Recycling Reuse Equipment Irrigation	Monitor Air Cooling Equipment Closed Loop Irrigation	Monitor Education Reuse Cooling Tower Ozonation Closed Loop Irrigation Landscape Plumbing	Monitor Education Cooling Tower Ozonation Irrigation
Water Use, MG/yr [b]										
Before Conservation	554	50 (1)	23 (1)	NA[a]	111 (1)	71	657	NA (5)	33	2 (1)
After Conservation	348	36 (1)	11 (1)	NA	11 (1)	53	292	NA (5)	23	0 (1)
Water Savings										
MG/yr [b]	206	14 (1)	12 (1)	3.3 (2)	100 (1)	18	365	NA (5)	10	2 (1)
Percent of previous use	37	28 (1)	52 (1)	NA	90 (1)	25	56	NA (5)	30	100 (1)
Cost Effectiveness										
Capital cost, $1,000	50 (2)	85	20	NA (3)	50	550	NA (3)	NA (5)	28	8 (2)
Annual Savings, $1,000/yr	81 (2)	83	78	29	153	107	NA	NA (5)	28	38 (2)
Payback Period, y [c]	0.6 (2)	1	0.3	NA (3)	0.3	3	NA (3)	NA (5)	1	0.2 (2)

[a] Not available or not applicable.

[b] Million gallons per year

[c] Payback period is capital cost divided by annual savings.

Notes:

(1) Water use rates apply only to one or more processes or operations involving conservation measures.

(2) Cost savings based on only a portion of conserved water (the portion with which costs could be associated).

(3) Capital costs not available for calculating payback period.

(4) Savings account for increases in production.

(5) Water conservation measures in original facility design.

Table II Summary of Case Study Results (continued)

MEASURES AND RESULTS / COMPANY	Metal Finishing Industry: Dyna-Craft	Metal Finishing Industry: Hi Density	Paper Reprocessing Industry: California Paperboard Corporation	Paper Reprocessing Industry: Container Corporation of America	Food Processing Industry: Gangi Bros.	
Conservation Measures	Equipment	Monitor Education Recycling	Recycling Reuse	Recycling Cooling Tower Equipment	Monitor Education Recycling Reuse Cooling Tower Equipment Optimization	
Water Use, MG/yr[b]						
Before Conservation	51	7.9	653	353	150	
After Conservation	37	5.6	182	170	56	
Water Savings						
MG/yr[b]	13	2.3	472	250 (4)	94	
Percent of previous use	25	29	72	71 (4)	63	
Cost Effectiveness						
Capital cost, $1,000	22	NA[a] (3)	150	200	77	
Annual Savings, $1,000/yr	129	64	767	348	130	
Payback Period, yr[c]	0.2	NA (3)	0.2	0.6	0.9	

[a] Not available or not applicable.

[b] Million gallons per year

[c] Payback period is capital cost divided by annual savings.

Notes:

(1) Water use rates apply only to one or more processes or operations involving conservation measures.

(2) Cost savings based on only a portion of conserved water (the portion with which costs could be associated).

(3) Capital costs not available for calculating payback period.

(4) Savings account for increases in production.

(5) Water conservation measures in original facility design.

CHAPTER 1

INTRODUCTION

The City of San Jose is actively pursuing water conservation programs covering residential, commercial, and industrial water use. The purpose of the water conservation programs is to reduce flows to the San Jose/Santa Clara Water Pollution Control Plant and thus delay construction of a new facility. This report describes a major component of the City of San Jose's industrial water conservation program.

Many industries in the San Jose area save water by implementing cost-effective conservation measures. This report describes 15 case studies of water-conserving companies, presenting water uses, conservation measures, water savings, and economic benefits. The case studies centered around four industrial groups in the San Jose area--electronics manufacturing, metal finishing, paper reprocessing, and food processing. The case study results show that water conservation measures can readily be transferred to other companies and other industries.

This chapter describes the study methodology and the water supply in the study area, and summarizes the organization of the remainder of the report.

STUDY METHODOLOGY

The project was sponsored by the City of San Jose, Office of Environmental Management in association with the California Department of Water Resources (DWR), Water Conservation Office, which provided major monetary support. The project was initiated in September 1987 and completed in February 1990. Brown and Caldwell Consultants was retained to conduct the case studies and prepare this report.

The City of San Jose created an Industrial Advisory Committee to review the progress and provide input on the developing case studies and this final report. Committee members included representatives from water utilities, industries, equipment vendors, and trade groups, as well as the City of San Jose and DWR.

The purpose of this project was to identify industrial water conservation technology, describe its effectiveness, and assess its cost-effectiveness. Specific objectives were:

1. Identify which technologies work best in reducing water use.
2. Identify how much water can be saved.
3. Identify water quality requirements for reuse or recycling applications.
4. Determine if the technology is cost-effective.
5. Summarize the information for use by water utilities.
6. Transfer the information to other facilities, industries, and communities.

WATER SUPPLY IN THE SAN JOSE AREA

The City of San Jose is located just south of the San Francisco Bay (see Figure 1). In this report, the San Jose area is considered to be northwestern Santa Clara County, extending west from San Jose to Saratoga and north to Palo Alto. This also includes such "Silicon Valley" cities as Santa Clara, Sunnyvale, and Cupertino.

The San Jose area receives its water from a combination of sources, including snowmelt from the Sierra Nevada Mountains through the Hetch Hetchy aqueduct, local groundwater, the South Bay Aqueduct, and San Felipe projects. Figure 2 shows these major water suppliers to the San Jose area. The San Francisco Water Department wholesales Hetch Hetchy water to San Jose area cities. Also, the Santa Clara Valley Water District acts as a water wholesaler to the various water retailers in the Santa Clara Valley.

Hetch Hetchy water is purer than the local groundwater: about 20 parts per million (ppm) of total dissolved solids (TDS) versus 200 ppm TDS for the groundwater. Local water utilities blend these supplies for delivery to customers. Drought conditions can increase the proportion of the higher TDS groundwater in a municipality's blend.

Santa Clara County manufacturing industries use 16 billion gallons of water annually, the fourth highest manufacturing use rate of California counties. About 4 billion gallons per year are used by electric and electronics industries, mostly in the study area. Other high water-use industries include food and kindred products, which use over 4 billion gallons annually.[1]

ORGANIZATION OF REPORT

The remainder of this report is organized as follows. Chapter 2 is an overview of industrial water conservation measures, describing general conservation approaches, applying conservation measures to specific water uses, and explaining the procedure for calculating economic benefits. Chapter 3 discusses the case study results for the four industrial groups evaluated, showing actual water and money savings at the participating companies. Conclusions and recommendations are presented in Chapter 4. The 15 case studies are appended to the report.

Figure 1. San Jose Area

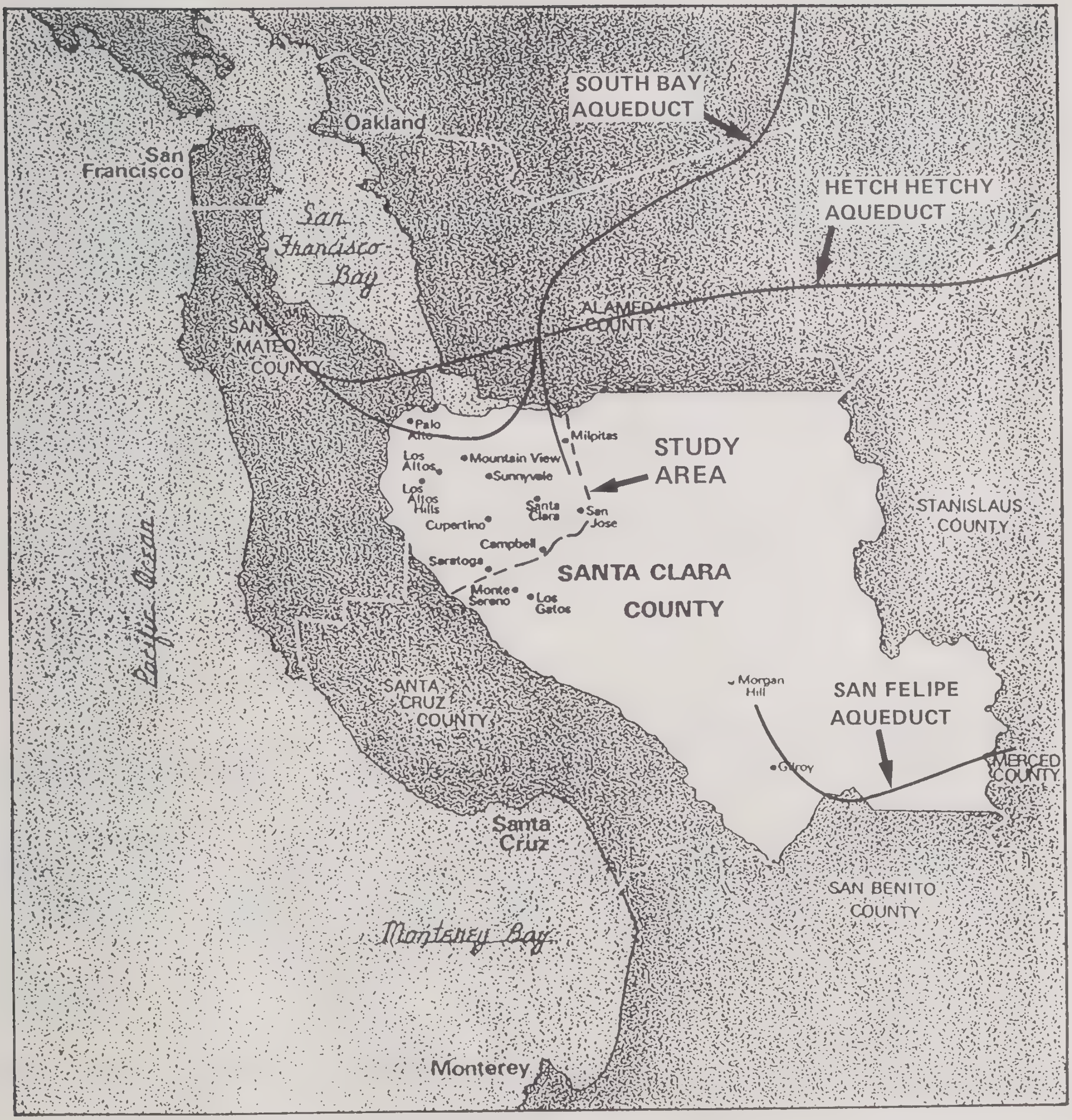
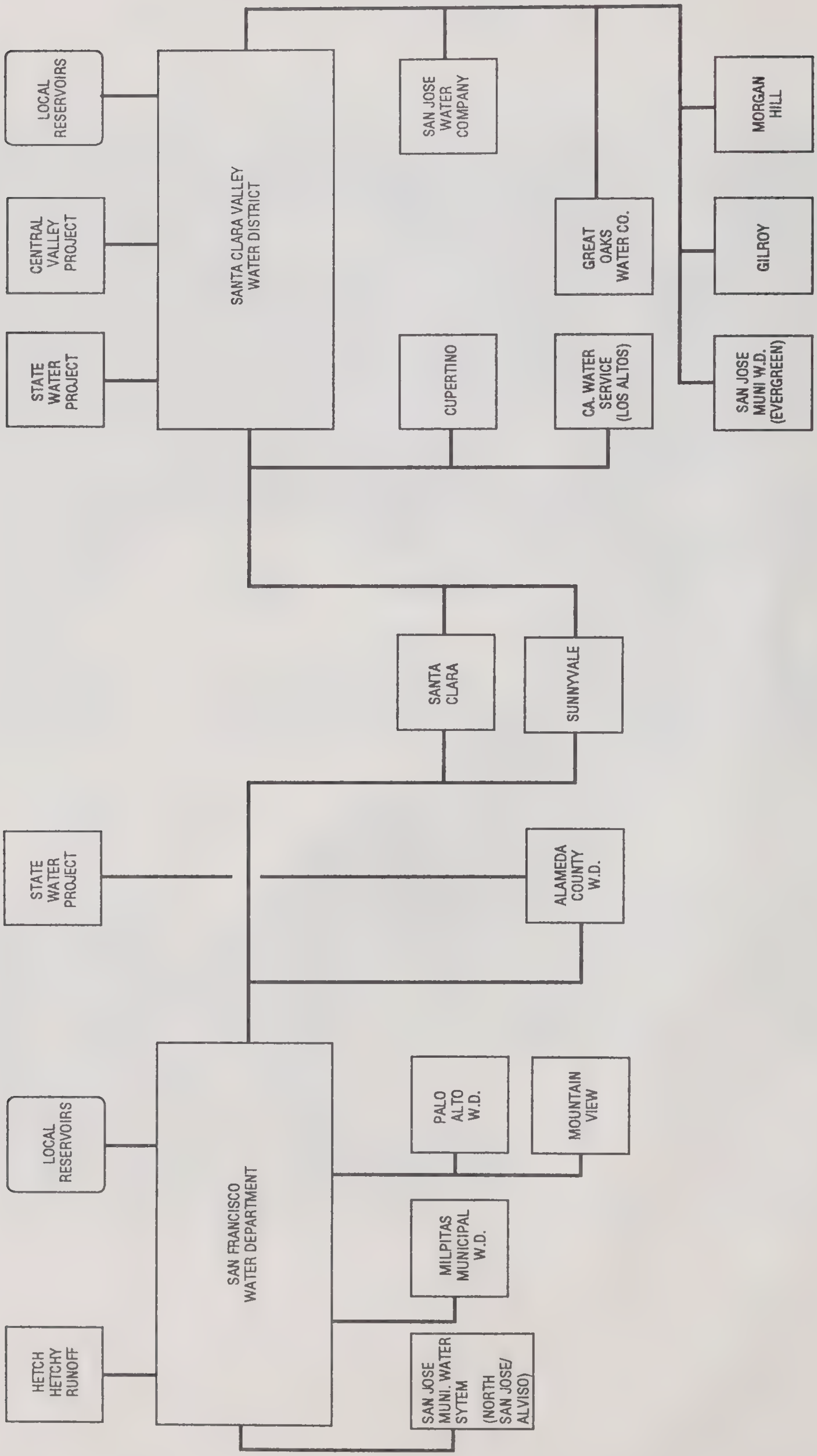


Figure 2. San Jose Area Water Hierarchy



CHAPTER 2

WATER CONSERVATION OVERVIEW

This chapter describes general conservation approaches identified in the case studies, then applies them to specific industrial water uses. Finally, a methodology for assessing the costs and benefits of water conservation is presented.

Historically, water conservation has been a low priority for most industries, because water is a relatively inexpensive cost item. In addition, a plentiful supply of fresh water is usually available. More recently, the concept of water conservation has gained prominence because of droughts and a heightened public awareness of the value of this strained resource.

GENERAL CONSERVATION APPROACHES

Industry's first step in conserving water is a commitment from management. The commitment is demonstrated by:

- Establishing water use as an important decision criterion for company operations.
- Announcing the priority of conservation to all personnel.
- Setting conservation goals.
- Training employees.
- Allotting resources.
- Acknowledging successes.

This commitment and comprehensive company involvement gives strength to specific conservation measures.

The conservation measures described below are monitoring, recycling, reuse, and reducing water use. This section provides background on these measures, citing exemplary case studies as illustrative references. Actual conservation results at the case study companies are presented in Chapter 3.

Monitoring

Monitoring provides baseline information about:

- Quantities of overall company use.
- Patterns of use (seasonal, hourly).
- Quantities and qualities of water use in individual processes.

This information can be used to set conservation goals and document results in a sound conservation program. A survey of water uses and water qualities guides the careful

selection of conservation measures. Gangi Bros. Packing Co. (Appendix E) maintains an excellent monitoring program to document and support its conservation efforts.

Water use monitoring is also a good way for industry to gain staff support for water conservation. Employees respond to conservation measures better when they can see results. They become more knowledgeable about water use rates and how they can affect water use. Water meters on individual pieces of water-using equipment provide employees with direct information about how water efficient they are in their jobs. Similarly, a manager in charge of a water conservation program can study records of total company water use to stay abreast of progress.

Facility inspections, such as organized checks of water-handling areas, prevent problems from going unnoticed. Some San Jose area companies conduct daily inspections to check for leaks and problems with equipment or operation. Inspectors should record meter readings and note specific changes in water use.

Recycling

Water is recycled by returning it to the same application in which it was initially used, as depicted in Figure 3. Often, a preliminary use alters or degrades the water so that it must be treated prior to subsequent use. For example, if rinse water is to be recycled, the contaminants the water picks up during a preliminary use must be removed prior to subsequent rinsing. The Hewlett-Packard Co. (Appendix B.3) case study demonstrates a model recycling program.

Elements of a recycling measure are:

1. Evaluate the minimum water quality needed for a given use.
2. Evaluate the degradation of water quality resulting from the use.
3. Determine the treatment steps, if any, needed to prepare used water for recycling.

Reuse

Water reuse is the application of wastewater from one process to a different process. Figure 4 depicts this approach. For example, reject water from a reverse osmosis process may be used to scrub fumes from a contaminated airstream. The following steps should be used in developing a reuse measure:

1. Determine the minimum water quality needed for a given use.
2. Identify which wastewater sources satisfy the water quality requirements.
3. Determine how the water can be physically transported to its new use.

IBM (Appendix B.5) was very successful with a water reuse program.

Figure 3. Simplified Schematic of Recycling

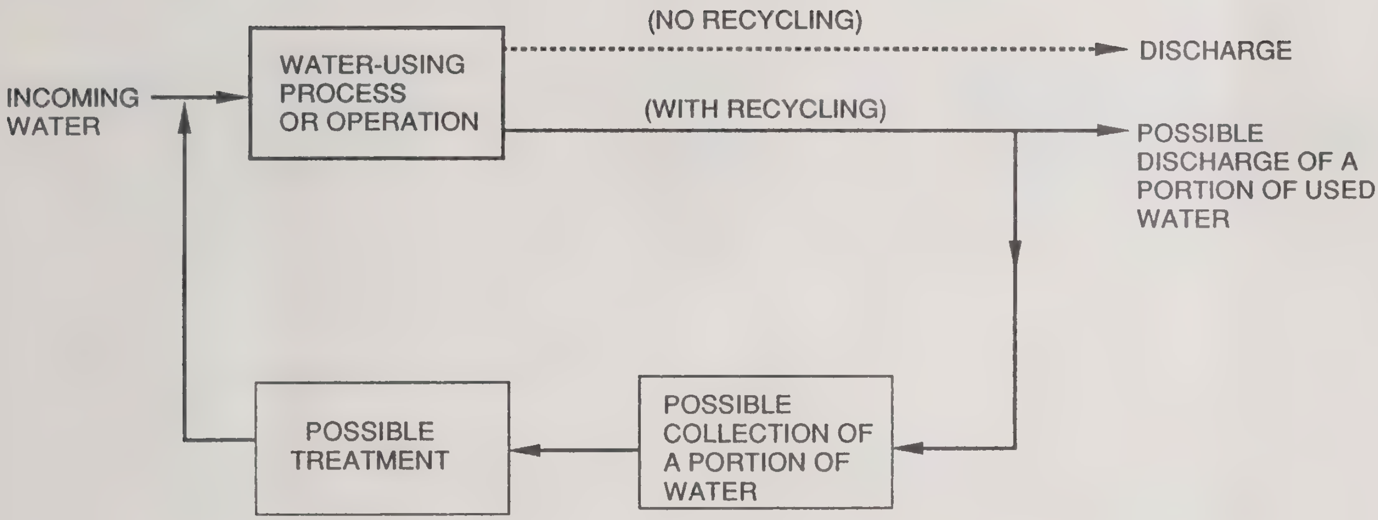
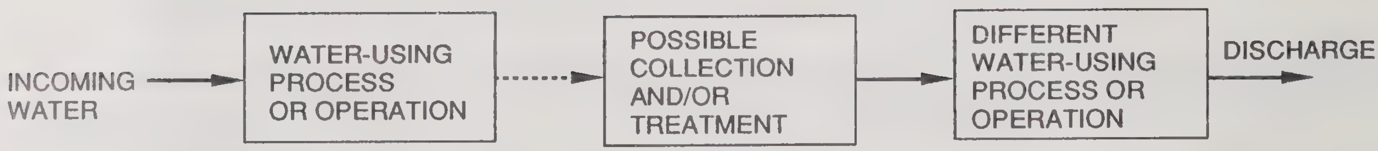


Figure 4. Simplified Schematic of Reuse



Reducing Water Use

When water is used excessively, reductions can be achieved by a variety of methods:

- Processes can be optimized to require less water; for example, excessive reject rates from reverse osmosis units can be turned down to design levels.
- Operations can be modified to reduce water use, as exemplified by converting from a continuous-flow system to a periodic water use system.
- Modify equipment, such as the installation of low-flow showerheads in employee washrooms and automatic shutoff valves or timers.
- Equipment can be replaced or installed (for example, installing cooling towers).
- Simply using less water to do the same job can reap benefits, such as more careful floor washdowns.

The elements of implementing a reduction measure are:

1. Evaluate the water quantity required for a given application.
2. Compare the required quantity with actual use to see if current use is excessive.
3. Evaluate alternative equipment or operation options which will conserve water.

Dyna-Craft, Inc. (Appendix C.1) instituted a simple but effective rinsewater reduction measure.

CONSERVATION MEASURES APPLIED TO SPECIFIC WATER USES

This section describes water conservation measures for cooling, rinsing, scrubbing, transporting materials, pulping, irrigating, and serving sanitary needs.

These water uses are common, and the potential conservation measures are widespread. A key point is that these measures implemented by the case study companies can be adopted by other similar facilities and also by different facilities with similar water uses. Many of the approaches described below--and the specific implementations discussed in Chapter 3--can be adopted or modified to benefit any company with water uses similar to those presented in this report.

Cooling

Cooling is one of the largest water uses in the United States. Nearly all the industries studied in this project use cooling water, either to cool heat-generating equipment (such

as pumps) or to condense gases in a thermodynamic cycle (such as refrigeration or steam condensation). Steam condensation is a high-temperature cooling application, where maximum cooling water temperatures often exceed 100 degrees Fahrenheit (F). Equipment cooling and refrigerant condensation generally occur at temperatures less than 100 degrees F.

The most water-intensive cooling method is "once-through" cooling, where the water contacts and lowers the temperature of a heat source, then is discharged after only one use. Recycling with recirculating cooling systems dramatically reduce water use by using the same water to perform several cooling duties.

Recirculating cooling water must be cooled on a cyclic basis. One water conservation technique to recirculate cooling water is using a cooling tower, where the cooling water loses heat when a portion of it is evaporated. A technique which involves no water loss is removing heat with an air heat exchanger (radiator). Figure 5 is a conceptual diagram of these methods.

The report next describes the following cooling water conservation approaches:

- Evaporative cooling.
- Ozonation.
- Air heat exchange.

Evaporative Cooling. A schematic of an evaporative cooling tower is presented in Figure 6. After contacting the heat source, recirculating cooling water enters the top of a tower and sprays downward. Air is blown upward through the tower, evaporating some of the cooling water. The water loses the latent heat of vaporization in this process, thereby lowering the water's temperature.

Figure 6 shows that water is lost from an evaporative cooling tower in three ways: (1) evaporation, (2) drift, and (3) blowdown. Evaporation losses occur when liquid water is converted to water vapor and exits the tower. Drift is unevaporated water carried out of the tower by the airflow; it has the same composition as the recirculating water. Blowdown is the recirculating water intentionally removed from the tower to control recirculating water quality. Makeup water is added to the recirculating cooling water stream to compensate for these losses.[2]

Blowdown reduction is the route to water conservation in evaporative cooling towers. Since the minimum blowdown volume depends on recirculating cooling water chemistry, the chemical concentration effects of recirculating water are explained below. Conventional treatment to solve the problems associated with cooling water is discussed. The use of blowdown is then described.

1. Concentration Effects. In an evaporative cooling tower, the dissolved salts present in the water (such as sodium, chloride, calcium, and sulfate ions)

Figure 5. Comparison of Once-Through Cooling with Recirculation Options

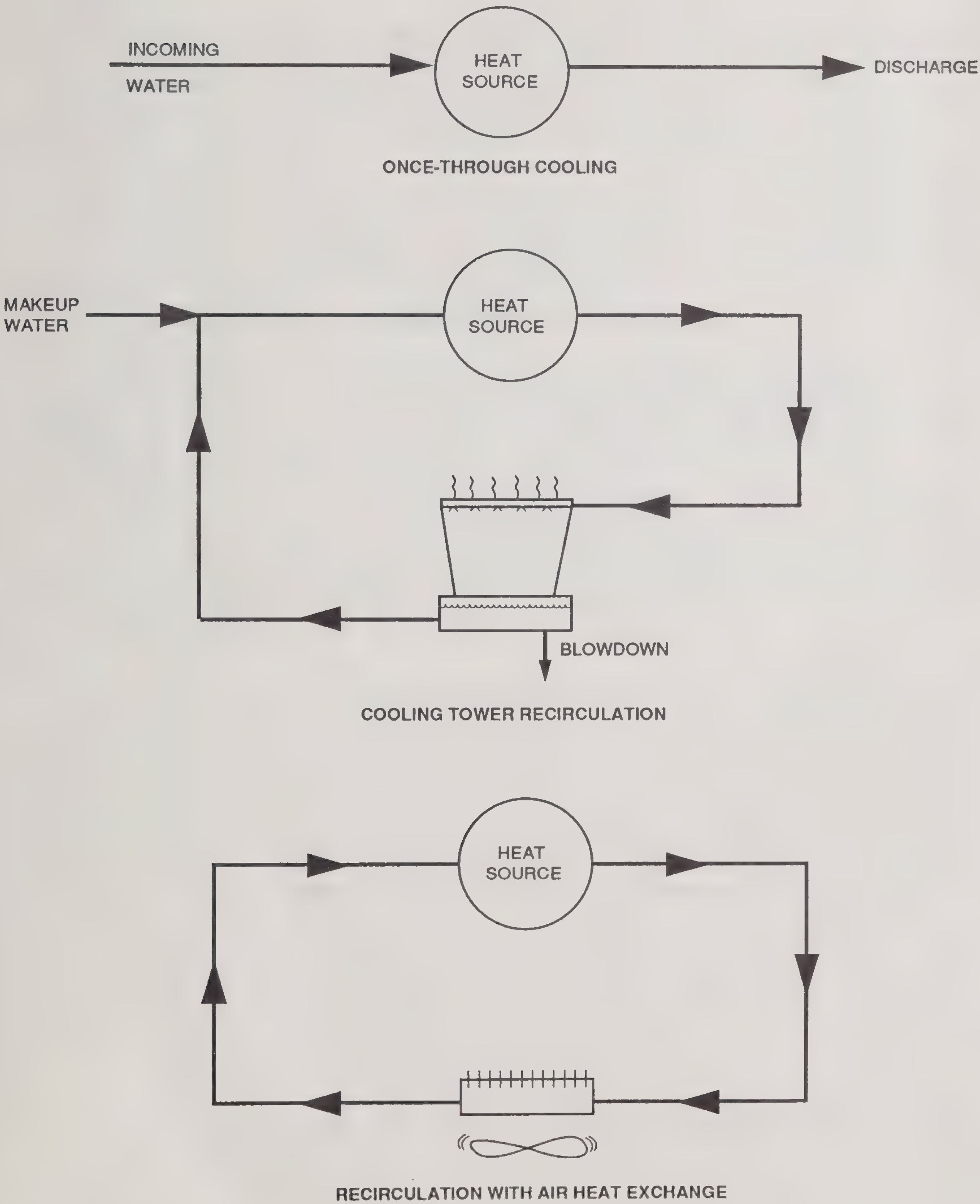
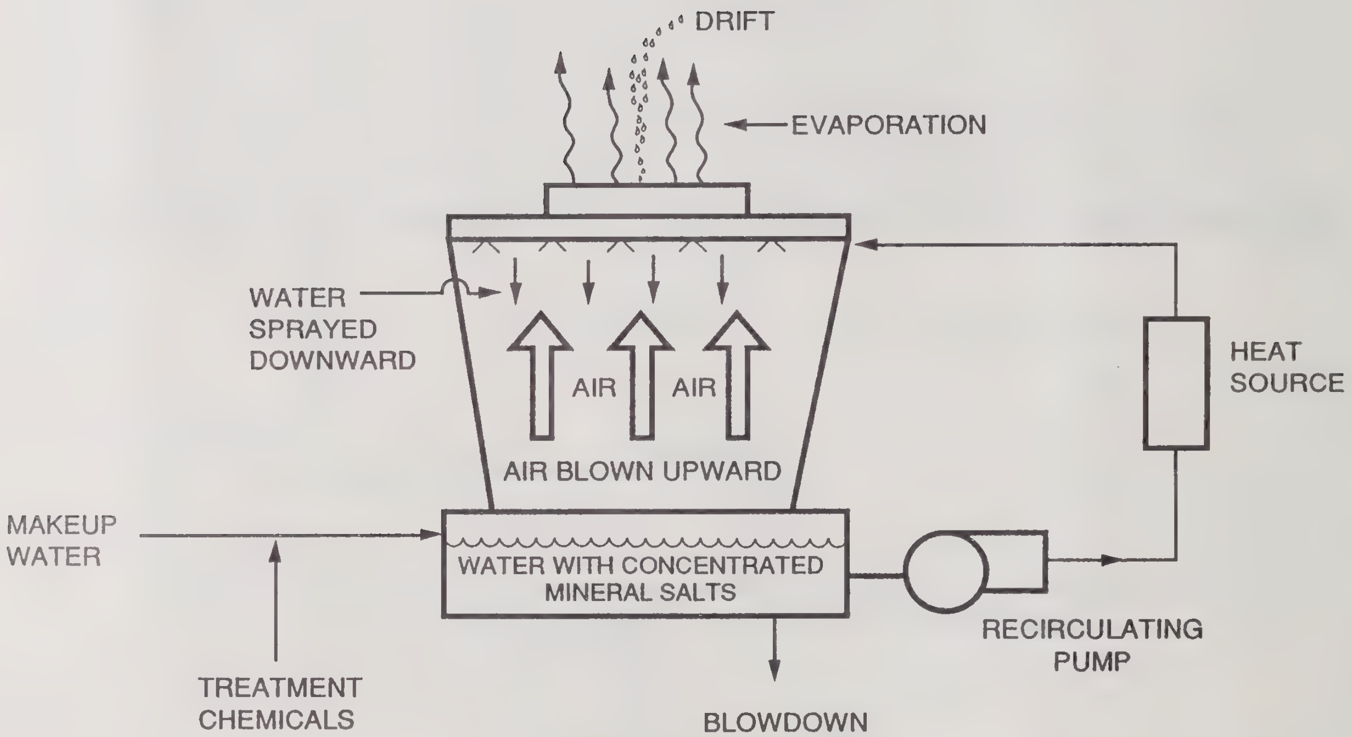


Figure 6. Typical Cooling Tower Operation



become increasingly concentrated during the process of evaporation. Thus, the recirculating water is of poorer quality (with higher salt content) than the makeup water.

2. Cooling Water Treatment. To maintain heat transfer functions, three problems must be combatted in evaporative cooling towers: (1) scale, (2) corrosion, and (3) biological growth. Scale occurs if the water becomes so concentrated that salts reach saturation and precipitate out of solution. The precipitates can adhere to heat exchanger surfaces, reducing heat transfer efficiency. Corrosion is a complex electrochemical attack on metal surfaces. Both scale and corrosion are promoted by water with high total dissolved solids (TDS). Biological growth, which occurs in almost all aquatic environments, can produce slime layers on heat exchanger surfaces, reducing efficiency. All three problems are normally controlled by a combination of water treatment and blowdown.

   Treatment has historically been accomplished by chemical addition. Certain chemicals, such as polyphosphates, inhibit scale formation. Corrosion control chemicals, such as chromates, are sometimes hazardous and are tightly regulated. Chlorine, another regulated chemical, is a common disinfectant to control biological growth. Various guidelines exist for traditional chemical treatment of cooling water, based on such water quality parameters as hardness, alkalinity, and TDS. A more recent treatment approach, ozonation, has been found to be a site-specific water-conserving alternative to chemical treatment. Ozonation is discussed in the next section.

3. Blowdown. The purpose of blowdown is to reduce TDS by removing a portion of poor quality recirculating water. The blowdown is replaced by high quality makeup water. This maintains recirculating water quality (TDS) at an acceptable level. Ideally, the volume of blowdown is only the amount needed to control scale, corrosion, and biological growth for the type of water treatment applied. The minimum blowdown volume depends on makeup water quality and the "cycles of concentration" with which the tower can operate satisfactorily. Cycles of concentration is a measure of the efficiency of water use in a cooling tower. Cycles of concentration are defined as the ratio of the TDS concentration in the recirculating water to the TDS concentration in the makeup water. Typical values for cycles of concentration range from about two to eight, depending on makeup water quality and the tower design.

   Blowdown volume is inversely proportional to the cycles of concentration. A system operating at four cycles of concentration blows down 25 percent (one-fourth) of the cooling tower makeup rate.

Ozonation Treatment of Cooling Water. The water savings resulting from using an evaporative cooling tower may be increased by treating cooling water with ozone instead of traditional chemicals. Ozone is an unstable and extremely reactive form of oxygen (O_3). In many equipment cooling and refrigerant condensing applications, ozone has successfully increased the cycles of concentration to 20 or more.[3,4] Operation at 20 cycles means a five-fold reduction in blowdown compared with a 4-cycle tower using traditional chemical treatment. With a high-quality makeup water, blowdown can be reduced to the point where the only blowdown removal occurs when the solids in the tower basin are vacuumed.

Ozonation of cooling water is a new technology and, despite many successful applications, is not completely understood. It has been found to be more appropriate in low-temperature applications, such as equipment cooling and refrigeration, as opposed to high-temperature steam condensation during electric power generation.

Ozone is a powerful oxidant, more effective than chlorine in disinfecting biological growth. It is not known exactly how ozone treatment controls scale and corrosion. It is theorized that ozone may combat corrosion by forming a protective oxide coating on the metal heat exchanger surface.[3] Studies have shown that salts may precipitate in ozonated water, but the precipitates do not adhere to heat exchanger surfaces, which is the primary problem with scale.[4] Instead, the precipitates may be removed by a sidestream filter. Alternatively, the precipitates may settle in the cooling tower basin where they can be removed by periodic vacuuming.

Air Heat Exchange. This cooling method operates on the same principal as a radiator in a car; that is, a fan blows air past finned tubes carrying the recirculating cooling water. Fins may be a series of stacked extrusions down the length of a tube (or a group of tubes), thin metal connections between tubes, or some other configuration. Their purpose is to increase the surface area of material which convects heat away from the water. Air heat exchangers may be relatively expensive compared with cooling towers.

Rinsing

Rinsing is a common industrial water use for removing debris or contamination from equipment or products. A promising way to conserve rinse water is recycling. This may require a treatment step to remove the rinsed contaminants before subsequent rinsing.

Rinse water may also be reused in applications where the rinsed contaminants do not preclude a subsequent use. Potential rinse water reuse applications include transporting materials, cooling, and scrubbing.

In the electronics and metal finishing industries, components are commonly rinsed with ultra pure deionized water to remove residual chemicals which components contact during manufacture. Because of its importance to these industries, deionized water rinsing merits further discussion. The paragraphs below describe the deionized water production, rinsing procedures, and conservation measures.

Deionized Water Production. Producing deionized water is relatively expensive. Common processes used to produce deionized water from municipal water include filtration (for particulates), ion exchange and reverse osmosis (for inorganics), carbon adsorption (for organics), and ultraviolet radiation (for biological contaminants). Some feedwater is lost during deionized water production, particularly with reverse osmosis, which creates a reject brine stream of approximately 25 to 35 percent of the input stream.

Rinsing Procedures. In electronics manufacturing, wafers containing integrated circuit chips are loaded onto trays, or "boats," which transport the wafers through a sequence of processing and rinsing steps. Rinsing takes place in continuously flowing baths of deionized water. Following the wafer rinse, the baths themselves are sometimes rinsed by plenum flushes, which discharge deionized water from the rim of the bath to remove contaminants from the sides and bottom of the bath.

Metal finishing companies may use deionized water to dip rinse processed metal components. Like the integrated circuits, the metal components may proceed through a sequence of processing and rinsing baths. The metal components may be individual pieces or continuous tapes. Contaminants or processing fluids (such as an acid), carried from one bath to the next, are called "dragout." The volume of water needed to rinse a component generally increases as the volume of dragout increases.

Conservation Measures. Recycling deionized rinse water is a promising option but requires careful control, particularly in the electronics industry, or contaminated rinse water may lead to component failure. Treatment for recycling may include many of the processes needed to produce deionized water from municipal water. Since the initial quantities of rinsewater in a given bath are likely to contain the highest contaminant concentrations, it may be sensible to recycle only the later, less contaminated portions of rinsewater, which are more economical to treat.

Reducing deionized water use is a common conservation measure, because historical use was often excessive when companies pursued maximum assurance against contamination. Reduction has been accomplished without compromising production quality by eliminating some plenum flushes, converting from continuous flow to intermittent systems, and improving control of deionized water use.

Because used deionized water from electronics rinsing applications may be more pure than municipal water and is costly to produce, it is a good candidate for reuse.

Air Scrubbing

Scrubbing consists of cleaning a contaminated airstream with a liquid. A typical scrubber is a tower in which the air is blown upward through the falling scrubbing liquid. The contaminants are transferred to the liquid, allowing the purified air to be discharged to the atmosphere. Depending on the air contaminants, chemicals may be added to the scrubbing liquid to improve efficiency. For example, alkaline chemicals may improve the scrubbing of acid mists.

Many plating and etching processes generate acid fumes, which need to be scrubbed prior to atmospheric discharge. The most commonly used water conservation technique applied to scrubbing is reuse. Reject water from reverse osmosis units, which might otherwise be discharged as wastewater, is used as the scrubbing liquid.

Transporting Materials

In an operation called "fluming," water conveys fruits or vegetables from delivery trucks to processing lines. After the trucks unload large bins of produce onto platforms, water is discharged into the bins to carry the produce through a bin gate into channels which lead to sorting equipment.

Two conservation measures apply to fluming. The first is recycling flume water through the bins and channels, which may be implemented without recycled water treatment. The second measure is water use reduction. For example, intermittent discharge may be able to transport the produce with less water than continuous water discharge.

Pulping

Pulping is a water use associated with the paper industry. In pulping, water is slurried with paper fibers to form a mixture with a consistency of 2 to 5 percent solids. The slurry or pulp then goes through a series of dewatering steps, first on a rolling screen, then on continuous belts. The dewatered pulp is an intermediate paper product which is processed further in the facility.

The water recovered during dewatering contains paper fibers. Fibers and water can both be recycled in subsequent pulping operations with little or no treatment.

Irrigating Landscape

Outdoor landscaping is a facility-specific situation not related to industry type. Irrigation requirements can be reduced by the following basic methods:

- Design landscape for low maintenance and low water requirements. Attractive drought resistant, native vegetation can be planted.

- Use and maintain efficient irrigation equipment such as drip or deep root systems.

- Distribute irrigation water uniformly over the landscape. Install equipment so that water is not directed over walkways or other nonvegetative areas.

- Schedule irrigation for maximum water use. Nighttime irrigation reduces water loss to evaporation.

Additional information about conserving irrigation water can be found elsewhere.[5,6,7]

Serving Sanitary Needs

Sanitary water uses include drinking water, sinks, toilets, and sometimes showers. Significant savings result from conscientious attention to water use. In addition, certain plumbing fixtures are designed to reduce water use. For example, toilets installed in California before 1978 flush with 5 to 7 gallons. Currently, California toilets must use no more than 3.5 gallons per flush. Toilets using 1.6 gallons are now available and will be required for all new buildings beginning in January 1992. Old toilets can be retrofitted with a toilet tank displacement, saving about 1 gallon per flush. Low-flow showerheads can be readily installed, cutting flow rates by 50 percent to less than 3 gallons per minute (gpm). Timers can be installed on faucets and showers.

COST/BENEFIT ANALYSES

Conserving water makes economic sense. The conservation measures just described can save an industrial facility thousands of dollars annually, primarily from reduced water and sewer use fees. This section describes how the cost analyses were conducted in this study.

Costs from implementing water conservation measures include both capital and operating and maintenance expenses. These are presented as annual costs and compared with annual economic benefits.

For comparison purposes, capital costs are provided on a common annual basis. The comparison assumes a 20-year design life at 12 percent interest. Amortization is accomplished by multiplying the capital cost by a factor 0.1339. The 20-year assumption

is arbitrary, used only so that all capital costs encountered in the case studies could be assessed on an equal basis.

Operating and maintenance costs include labor, power, water, sewer use fees, chemicals, and materials. Case study company personnel usually supplied estimates of both capital and operating and maintenance costs.

Economic benefits are normally avoided costs associated with municipal water and sewer fees and deionized water production costs. This cost of water in the San Jose area is about $1 per thousand gallons. Sewer use fees are slightly higher, up to $2 per thousand gallons. Costs to produce deionized water range from $5 to $20 per thousand gallons, an order of magnitude higher than municipal water costs.

A cost/benefit analysis consists of amortizing capital costs and adding operating and maintenance costs to obtain the annual cost associated with conservation measures. Then the avoided water, sewer, and deionized costs are calculated, as well as any other known savings, such as labor or chemicals. The difference between costs and savings is the annual economic benefit. The payback period is then calculated by dividing the capital cost by the annual benefit.

CHAPTER 3

CASE STUDY RESULTS

This chapter describes the case studies and presents an overview of the results. An examination of each industrial category follows, describing the industry, its typical water uses, the conservation measures adopted by the participating companies, the water savings, and the costs and benefits. For more information, refer to the specific case studies in the appendixes. The case studies contain more detailed discussions of results and data regarding company size, employment, or production rates.

CASE STUDY METHODOLOGY

The case study project documented industrial water conservation measures at 15 San Jose area companies. Table 1 lists the participating companies and the cities where they are located, so that the locations can be indexed to the cities displayed on Figure 1 (see page 9), the San Jose area. The 15 companies covered four industrial categories, listed below along with the number of case studies per category.

1. Electronics manufacturing (10)
2. Metal finishing (2)
3. Paper reprocessing (2)
4. Food processing (1)

The high proportion of electronic manufacturers reflects their prominence in the San Jose area.

The case studies were initiated by a letter from the City of San Jose inviting the company to participate in the project. Interested companies were contacted by Brown and Caldwell to arrange a site visit. During the visit, Brown and Caldwell gathered information about the facility, water use, conservation measures, water savings, and costs. The voluntary assistance from industrial personnel was vital to project success.

The objectives of the case studies were to obtain the following information:

1. Water balance quantifying all significant water uses.
2. Quality requirements of all water uses.
3. Prior history of water use reduction.
4. Examples of multiple recycling of water, successive use, substitution of water sources, use of reclaimed wastewater.
5. Technology employed and its costs and benefits.
6. Potential water reuse opportunities--quantity and quality requirements.
7. Possible reduced process use through equipment replacement or process change.
8. Benefits and costs for identified water-use reductions.

Table 1. Case Study Companies

Electronics Industry	Location
1. Advanced Micro Devices, Inc.	Sunnyvale, CA
2. Exel Microelectronics, Inc.	San Jose, CA
3. Hewlett-Packard Co.	Palo Alto, CA
4. Intel Corporation	Santa Clara, CA
5. International Business Machines, Corp.	San Jose, CA
6. International Microelectronic Products	San Jose, CA
7. National Semiconductor Corporation	Santa Clara, CA
8. Spectra Diode Laboratories, Inc.	San Jose, CA
9. Tandem Computers Incorporated	Cupertino, CA
10. Xerox Palo Alto Research Center	Palo Alto, CA
Metal Finishing Industry	
11. Dyna-Craft, Inc.	Santa Clara, CA
12. Hi Density Disc Manufacturing, Inc.	San Jose, CA
Paper Reprocessing Industry	
13. California Paperboard Corporation	Santa Clara, CA
14. Container Corporation of America	Santa Clara, CA
Food Processing Industry	
15. Gangi Bros. Packing Co.	Santa Clara, CA

The success in achieving all these objectives in each case study depended on the amount of information available from the participating companies. The case studies are presented in Appendixes B through E.

OVERVIEW OF RESULTS

Table 2 presents a matrix of case study companies and conservation measures. The companies are grouped by industrial category. The most common conservation measures are:

- Water use monitoring.
- Employee education.
- Recycling.
- Reuse.
- Cooling tower use.
- Equipment modification.
- Improved landscape irrigation.

Some companies adopted comprehensive conservation programs, while others focused on a few specific measures.

The case study results are summarized in Table 3. The table shows:

- Each company's water conservation measures.
- Water savings in million gallons per year.
- Water savings in percent of preconservation use.
- Capital costs of water conservation measures.
- Annual monetary savings resulting from conservation.
- Payback period $= \dfrac{\text{capital costs}}{\text{annual savings}}$

For some companies, water use rates apply to total facility use; whereas, for others, only the use rates associated with a conservation measure are listed (for example, the water used for cooling). This is noted in the table. Similarly, the dollar savings may apply to a specific conservation measure or to the entire program, depending on the available economic information.

Combined water consumption of the case study companies was reduced more than 1 billion gallons per year by conservation measures, enough to satisfy the needs of 7,000 homes for 1 year (assuming 400 gallons per household per day). Dollar savings total about $2 million per year. These cost-effective conservation measures could readily be used by other facilities.

Table 2. Water Conservation Measures at Case Study Companies

COMPANY / CONSERVATION MEASURE	Electronics Manufacturing Industry										Metal Finishing Industry		Paper Reprocessing Industry		Food Processing Industry
	Advanced Micro Devices	Exel	Hewlett-Packard	Intel	IBM	International Microelectronic Products	National Semiconductor	Spectra Diode Laboratories	Tandem Computers	Xerox	Dyna-Craft	Hi Density	California Paperboard Corporation	Container Corporation of America	Gangi Bros.
MONITORING	●	●	●			●	●	●	●	●		●			●
EMPLOYEE EDUCATION	●						●		●	●		●			●
RECYCLING							●					●	●	●	●
RECYCLING WITH ADVANCED TREATMENT			●												
REUSE		●	●		●	●	●		●				●		●
COOLING TOWER (WATER RECIRCULATION)		●		●	●	●			●	●				●	●
COOLING WATER OZONATION		●		●					●	●					
AIR COOLING								●							
EQUIPMENT MODIFICATION	●				●	●	●	●			●				●
EQUIPMENT SELECTION														●	
PROCESS OPTIMIZATION	●	●													●
CLOSED LOOP SYSTEM								●	●						
IMPROVED IRRIGATION	●	●			●		●	●	●	●					
LANDSCAPE MODIFICATION					●				●						
LOW-FLOW PLUMBING					●				●						

Table 3 Summary of Case Study Results

MEASURES AND RESULTS \ COMPANY	Advanced Micro Devices	Exel	Hewlett- Packard	Intel	IBM	International Microelectronic Products	National Semiconductor	Spectra Diode Laboratories	Tandem Computers	Xerox
	Electronics Manufacturing Industry									
Conservation Measures	Monitor Education Equipment Optimization Irrigation	Monitor Reuse Cooling Tower Ozonation Optimization Irrigation	Monitor Recycling Reuse	Cooling Tower Ozonation	Reuse Cooling Tower Equipment Irrigation Landscape Plumbing	Monitor Reuse Cooling Tower Equipment	Monitor Education Recycling Reuse Equipment Irrigation	Monitor Air Cooling Equipment Closed Loop Irrigation	Monitor Education Reuse Cooling Tower Ozonation Closed Loop Irrigation Landscape Plumbing	Monitor Education Cooling Tower Ozonation Irrigation
Water Use, MG/yr[b]										
Before Conservation	554	50 (1)	23 (1)	NA[a]	111 (1)	71	657	NA (5)	33	2 (1)
After Conservation	348	36 (1)	11 (1)	NA	11 (1)	53	292	NA (5)	23	0 (1)
Water Savings										
MG/yr[b]	206	14 (1)	12 (1)	3.3 (2)	100 (1)	18	365	NA (5)	10	2 (1)
Percent of previous use	37	28 (1)	52 (1)	NA	90 (1)	25	56	NA (5)	30	100 (1)
Cost Effectiveness										
Capital cost, $1,000	50 (2)	85	20	NA (3)	50	550	NA (3)	NA (5)	28	8 (2)
Annual Savings, $1,000/yr	81 (2)	83	78	29	153	107	NA	NA (5)	28	38 (2)
Payback Period, yr[c]	0.6 (2)	1	0.3	NA (3)	0.3	3	NA (3)	NA (5)	1	0.2 (2)

[a] Not available or not applicable.

[b] Million gallons per year

[c] Payback period is capital cost divided by annual savings.

Notes:

(1) Water use rates apply only to one or more processes or operations involving conservation measures.

(2) Cost savings based on only a portion of conserved water (the portion with which costs could be associated).

(3) Capital costs not available for calculating payback period.

(4) Savings account for increases in production.

(5) Water conservation measures in original facility design.

Table 3 Summary of Case Study Results (continued)

COMPANY / MEASURES AND RESULTS	Metal Finishing Industry: Dyna-Craft	Metal Finishing Industry: Hi Density	Paper Reprocessing Industry: California Paperboard Corporation	Paper Reprocessing Industry: Container Corporation of America	Food Processing Industry: Gangi Bros.	
Conservation Measures	Equipment	Monitor Education Recycling	Recycling Reuse	Recycling Cooling Tower Equipment	Monitor Education Recycling Reuse Cooling Tower Equipment Optimization	
Water Use, MG/yr [b]						
Before Conservation	51	7.9	653	353	150	
After Conservation	37	5.6	182	170	56	
Water Savings						
MG/yr [b]	13	2.3	472	250 (4)	94	
Percent of previous use	25	29	72	71 (4)	63	
Cost Effectiveness						
Capital cost, $1,000	22	NA[a] (3)	150	200	77	
Annual Savings, $1,000/yr	129	64	767	348	130	
Payback Period, yr [c]	0.2	NA (3)	0.2	0.6	0.9	

[a] Not available or not applicable.

[b] Million gallons per year

[c] Payback period is capital cost divided by annual savings.

Notes:

(1) Water use rates apply only to one or more processes or operations involving conservation measures.

(2) Cost savings based on only a portion of conserved water (the portion with which costs could be associated).

(3) Capital costs not available for calculating payback period.

(4) Savings account for increases in production.

(5) Water conservation measures in original facility design.

ELECTRONICS MANUFACTURING INDUSTRY

The San Jose area is home to many electronics manufacturers, spawning the area's nickname, "Silicon Valley." These companies develop, test, manufacture, and market semiconductor chips, integrated circuits, and other electronic components.

Water Uses

One of the largest water uses in the electronics industry is the rinsing of precisely manufactured components with deionized water. During manufacture, electronic components may contact numerous chemicals, such as alkaline solutions, acids, dopants, oxidants, and peroxides. Typically, components are immersed in a series of chemical solutions. The solution must be rinsed from the component after each immersion. The industry uses ultra pure deionized water for this rinsing, because less pure water may contaminate the component, leading to failure.

The electronics industry also uses water for cooling, fume scrubbing, and nonmanufacturing purposes, such as landscape irrigation and sanitation.

Conservation Measures

Because of the large number of electronics companies studied in this project, their conservation measures are divided into categories of water use. Measures are described for deionized water rinsing, fume scrubbing, and cooling.

Deionized Water Rinsing. Hewlett-Packard recycles deionized rinsewater, using a rinsewater diversion, analysis, and treatment system (please see the Hewlett-Packard case study in Appendix B.3). The key to recycling is recognizing that:

1. The initial quantities of deionized water used to rinse integrated circuit wafers contain the heaviest amounts of contaminants.
2. Used rinsewater from later during the same rinse contains fewer contaminants.

Therefore, when the wafer boat first enters the rinse bath, the rinsewater flowing through the bath is not recycled but, instead, diverted to an acid waste treatment system. After about 90 seconds, the diversion assembly switches the drain valves and delivers the rinse water to a recycling treatment system. This rinsewater can be economically treated by activated carbon adsorption, cartridge filtration, and ultraviolet sterilization. Hewlett-Packard estimates that this saves about 8.8 million gallons per year of deionized water, or 44 percent of the deionized water use at this application. This system could readily be adopted by any facility with a similar deionized water application.

National Semiconductor (Appendix B.7) recycles deionized rinsewater that is contaminated only with particulate matter. Cartridge filters are used to remove the particulate matter and allow recycling of the deionized water. Water savings amount to over 200 million gallons per year.

Most conservation measures of the case study electronics companies were equipment modifications to reduce deionized water waste. For example, National Semiconductor and Spectra Diode Laboratories (Appendix B.8), eliminated plenum flushes at the rinse tanks. International Microelectronic Products (Appendix B.6) converted deionized water rinse sinks from continuous flow to intermittent flow, using water only when integrated circuit water boats are dipped. Advanced Micro Devices (Appendix B.1) replaced continuous flow at deionized water faucets with programmed rinser dumps, saving about 50 million gallons per year of deionized water, amounting to 9 percent of the total water use at Advanced Micro Devices before conservation measures were implemented.

Fume Scrubbing. Reuse for fume scrubbing is a common water conservation measure in the electronics industry. Several companies--Exel, Hewlett-Packard, International Microelectronic Products, and Tandem Computers Incorporated (Appendixes B.2, B.3, B.6, and B.9, respectively)--reused reverse osmosis reject water to irrigate landscape or scrub fumes generated during chemical processing of components. Such measures are promising for any facility operating a reverse osmosis unit.

Tandem Computers Incorporated recirculates scrubbing water in a closed system. Spectra Diode Laboratories recirculates municipal water for fume scrubbing.

Cooling. Many of the case studies noted cooling water use at electronics companies. The water usually cooled heat-generating equipment (such as vacuum pumps) or the building air conditioning condenser water. Cooling towers were frequently operated to recycle the cooling water, requiring about 25 percent of the water use of wasteful once-through cooling.

IBM (Appendix B.5) treated industrial wastewater and reused it as makeup water for evaporative cooling towers. Two benefits resulted:

1. Municipal water was conserved and replaced by treated wastewater.
2. Total makeup water requirements for the cooling tower were reduced because the treated industrial wastewater was purer than municipal water.

Thus, IBM saved 100 million gallons per year of municipal water, or 90 percent of the previous cooling water requirement.

Four companies (Exel, Intel, Tandem Computers Incorporated, and Xerox, in Appendixes B.2, B.4, B.9, and B.10, respectively) reduced water use further by treating the recirculating cooling water with ozone, rather than traditional

chemicals. Spectra Diode Laboratories conserved by using air to remove heat from the cooling water, virtually eliminating cooling water loss.

Cooling towers should be considered at any facility that uses water for cooling. Ozonation and air cooling are promising cooling tower management options worthy of investigation.

Cost Savings

Hewlett-Packard's recycling and reuse programs save about $78,000 per year. The payback period for their investment was about 0.3 years. Other Hewlett-Packard facilities in the San Jose area also use similar water conservation measures.

Large cost savings, about $100,000 per year, were achieved by Advanced Micro Devices, IBM, and International Microelectronic Products. For the latter company, the payback period was 3 years; for the others, it was less than a year.

Companies where ozonation was an important conservation measure--Exel, Intel, Tandem, and Xerox--saved about $30,000 per year, with payback periods ranging up to 1 year.

METAL FINISHING INDUSTRY

Metal finishing improves the surface of metal by various methods, such as cleaning, baking, etching, coating, plating, and polishing. Metal components can be individual pieces (as with Hi Density Disc Manufacturing Company, Inc., in Appendix C.2) or continuous tapes (as with Dyna-Craft, in Appendix C.1).

Water Uses

Metal finishing generally involves immersing components in a series of chemical solutions, with rinsing after each step. Rinsing usually uses the most water at a facility. Deionized rinse water is often required, particularly in the latter processing stages. Other water uses at metal finishing facilities typically include cooling, sanitation, and irrigation.

Conservation Measures

Dyna-Craft reduced deionized water use by installing "Air Knives" with plating and rinse baths (see the Dyna-Craft case study). Air knives are nozzles which direct compressed air to blow dragout off the metal component before the component leaves the bath, thus reducing the amount of rinse water needed. Conserved water amounts to 13 million gallons per year, 25 percent of previous rinse water use.

Hi Density Disc recycles deionized rinse water, treating it with a cartridge filter between uses. Annual savings are 2.3 million gallons of deionized water, which is 29 percent of previous use.

Cost Savings

Rinsewater recycling at Hi Density Disc saves $64,000 per year, based on reduced water and sewer use fees and reduced deionized water production costs. Dyna-Craft saves $129,000 per year using the Air Knives to reduce dragout.

PAPER REPROCESSING INDUSTRY

Two San Jose area companies, California Paperboard Corporation (Appendix D.1) and Container Corporation of America (Appendix D.2), manufacture paperboard and/or cardboard from recycled paper fibers. Paper and paperboard manufacturing require large amounts of water.

Water Uses

In pulping, water is slurried with paper fibers to form a mixture with a consistency of 2 to 5 percent solids. The slurry or pulp then goes through a series of dewatering steps, first on a rolling screen, then on continuous belts. During dewatering, fibers remaining on rollers or belts must be rinsed. Other water uses include cooling, landscape irrigation, and sanitation.

Conservation Measures

Both companies reclaim water during pulp dewatering. It is either returned as slurry water in subsequent pulping or treated for reuse. Water treatment removes fibers by screening or clarification. Recovering the fibers is a valuable side benefit. Treated water, if sufficiently free from fibers, can be used for felt needle showers, whose spray valves require particle-free water. Other reuse or recycle options include cooling, washdowns, and pulping.

The combination of recycling and reusing conserves large amounts of water. California Paperboard Corporation uses 470 million gallons less per year than in preconservation times. Accounting for production increases, Container Corporation of America uses an estimated 250 million gallons less. Each of these reductions is about 70 percent of previous water use.

Reclaiming pulp slurry water is a readily transferable conservation method for the paper industry. Recovering the fibers adds further value.

Cost Savings

Both companies realize large cost savings. California Paperboard Corporation and Container Corporation of America, annually save $767,000 and $348,000, respectively. Each payback period was less than 1 year.

FOOD PROCESSING INDUSTRY

Gangi Bros. Packing Company (Appendix E), a tomato cannery, is the only food processing company studied in this project.

Water Uses

Gangi Bros. uses water for fluming, which transports tomatoes from bins to processing lines. The other significant use is cooling.

Conservation Measures

Flume water is recycled, conserving large quantities relative to the previous one-use fluming approach. Water from one flume is recycled to the bin and back to the flume again. Recycling fluming water is a readily transferrable conservation measure, adaptable to other canneries and food processing employing this material transport water use.

The amount of fluming water used was reduced by modifying the bin discharge valves. Using intermittent discharges of short duration but high volume, less water is needed overall to remove the tomatoes from the bins.

Gangi Bros. operates three evaporative cooling towers in lieu of once-through cooling. This constitutes a significant savings relative to once-through cooling.

Total water reduction at Gangi Bros. is 94 million gallons per year. This amounts to 63 percent of the 1983 water use.

Cost Savings

Estimated annual savings from water conservation measures at Gangi Bros. are $130,000. The payback period was less than 1 year.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

This report describes water conservation measures adopted by 15 San Jose area companies representing the electronics manufacturing, metal finishing, paper reprocessing, and food processing industries.

Based on case study results, the following conclusions are drawn:

1. Common water conservation measures were:

   - Water use monitoring.
   - Employee education.
   - Recycling.
   - Reuse.
   - Cooling tower use.
   - Equipment modification.
   - Improved landscape irrigation.

These measures were implemented in most of the case study industrial categories studied. The measures can generally be applied to any industrial facility seeking water use reduction.

2. Specific conservation actions are listed below, which exemplify how case study companies developed less common, but cost-effective, measures. The company is listed with reference to its location in the appendices. These examples provide excellent opportunities for other companies to reap large savings in water use.

   a. Recycling deionized rinsewater, as developed by Hewlett-Packard (Appendix B.3). The key to this system was recognizing that the first quantities of used rinsewater contained most of the contaminants and thus were not suitable for recycling. Rinsewater collected after the first 90 or more seconds of rinsing was targeted for recycling, since this water could be treated cost-effectively.

   b. IBM (Appendix B.5) reused treated wastewater as makeup for a recirculating cooling tower. Makeup fresh water was conserved. In addition, because the wastewater is significantly derived from deionized water use, it is purer than tap water, with the result that the cooling tower discharges much less blowdown.

   c. The use of Air Knives reduced rinsewater use at Dyna-Craft (Appendix C.1). This inexpensive system cut the amount of dragout entering rinsewater channels.

d. Both paper reprocessing companies, California Paperboard Corporation and Container Corporation of America (Appendixes D.1 and D.2, respectively), recycled pulping water recovered during the dewatering processes. This is a logical approach, since it recycles the paper fibers as well.

e. Many companies operate reverse osmosis as part of deionized water production systems. Advanced Micro Devices and Exel Microelectronics (Appendixes B.1 and B.2, respectively) trimmed the reject stream rate by process optimization. Furthermore, several companies reused reject water to scrub chemical fumes.

f. A number of specific actions reduced deionized rinsewater use. National Semiconductor and Spectra Diode Laboratories (Appendixes B.7 and B.8, respectively) eliminated plenum flushes, deciding that the flushes were unnecessary. Advanced Micro Devices (Appendix B.1) and International Microelectronic Products (Appendix B.6) eliminated continuous trickle flow of deionized water at rinse stations. Advanced Micro Devices installed a programmed rinser dump system which intermittently discharges deionized water. International Microelectronic Products switched to using deionized water only during rinsing operations.

g. Exel Microelectronics, Intel Corporation, Tandem Computers, and Xerox (Appendixes B.2, B.4, B.9, and B.10, respectively) successfully treat recirculating cooling water with ozone, reducing blowdown significantly. In lower temperature applications, ozone treatment results in less scale formation on heat exchanger surfaces, allowing cycles of concentration up to 20 or more.

h. Tandem Computers (Appendix B.9) installed a computer-controlled landscape irrigation system, based on plant water needs. This sophisticated approach derives maximum utility from irrigation water.

3. Conservation measures effectively reduced water use at the case study companies. Water savings ranged from 2 million to 470 million gallons per year. Typical reductions were 30 to 40 percent of preconservation use.

4. Companies achieved significant economic benefits by conserving water. Average savings are about $50,000 per year, with several companies saving more than $100,000 per year. Payback periods on capital investment were usually less than 1 year.

5. The cost-effective water conservation measures successfully used at the case study facilities can readily be adopted by other facilities and other industries.

The following recommendations are presented:

1. Prepare a general guidance on industrial water conservation. Elements of the guidance would include:

    a. Corporate commitment.
    b. Water use monitoring.
    c. Procedures for identifying recycling, reuse, and reduction opportunities.

2. Expand industrial water conservation efforts in the San Jose area. The success of the 15 case study companies demonstrates that potential savings are significant.

3. Publish the results of this project on a statewide or nationwide basis.

APPENDIX A

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APPENDIX B

CASE STUDY COMPANIES--ELECTRONICS MANUFACTURING INDUSTRY

B.1 - Advanced Micro Devices, Inc.

B.2 - Exel Microelectronics, Inc.

B.3 - Hewlett-Packard Co.

B.4 - Intel Corporation

B.5 - International Business Machines, Corp.

B.6 - International Microelectronic Products

B.7 - National Semiconductor Corporation

B.8 - Spectra Diode Laboratories, Inc.

B.9 - Tandem Computers Incorporated

B.10 - Xerox Palo Alto Research Center

B.1

WATER CONSERVATION AT ADVANCED MICRO DEVICES, INC.

Brown and Caldwell
December 29, 1989

WATER CONSERVATION AT ADVANCED MICRO DEVICES, INC.

Description of Facility and Business

Advanced Micro Devices, Inc. (AMD) is a semiconductor manufacturer which occupies 24 buildings with about 1.4 million square feet of space in Sunnyvale and Santa Clara, California. This report focuses on 7 of these buildings at which water conservation actions were monitored. The normal operating schedule at these facilities are 24 hours per day, 7 days per week.

City water sources supply almost all of AMD's water requirements. Water uses at AMD include cooling water for one 900-ton, three 650-ton, and three 450-ton chillers, water sprays for scrubber systems, deionized water (DIW) rinses, sanitary water, and landscaping. City water use over the first six months of 1989 averaged 1,270 hundred cubic feet (ccf) per day (950,000 gallons per day).

AMD is also currently using some reclaimed groundwater for cooling tower make-up. Before reuse, it is treated using carbon filtration and air stripping. The groundwater reclamation project is not addressed in this case study, because, while it impacted water use, it is not actually a conservation measure.

AMD's motivation to pursue water conservation was to ensure uninterrupted operations during the drought and reduce operating costs. Reduced water use would lower water costs as well as wastewater discharge fees. Recent drought conditions and depleted groundwater supplies provided additional motivation for developing effective ways to save water.

Description of Conservation Actions

The manufacture of semiconductor chips requires the use of large volumes of ultra-pure DIW to rinse chemicals from wafers. Chips are produced as circular flats, or wafers, and a typical water use figure is about 100 gallons per wafer. Insufficient rinsewater quantity or contaminants in rinsewater increase the risk of leaving microscopic contaminants on the chips, leading to chip failure. Therefore, chipmakers must be extremely cautious when applying water conservation measures.

The major water conservation action at AMD has been modification of the rinse sinks at its wafer fabrication facility. Prior to 1989, these sinks were operated with a trickle flow of 0.25 to 3 gallons per minute (gpm) to prevent bacterial growth. With over 50 sinks in operation, DIW use at this time was between 280 and 300 gpm. This process has been changed to a programmed rinser dump which uses much less water overall. Instead of a constant trickle flow, rinses are programmed to dump about every 20 minutes when a sink is not in use.

Other process changes to reduce water use include the improvements to the DIW production system. AMD uses two reverse osmosis systems with a total capacity of 400 gpm to provide DIW to the 40,000 square foot wafer fabrication facility. After analyzing water quality needs and reviewing the original design, reverse osmosis reject rate was reduced from a typical range of 32 to 35 percent down to 29 percent. This was a cost-free process optimization.

A future consideration is to reuse cooling water for irrigation. However, used cooling water is even more concentrated with dissolved material than the cooling water make-up. Thus, salt build up may create a problem. AMD has already cut landscape water use by 10 to 15 percent by reducing sprinkler cycling times and watering only at night to reduce evaporation.

AMD has also established an employee awareness program to promote water conservation in all aspects of the workplace. Actions under this program included writing articles in the company newsletter and issuing memos along with paychecks which included charts of groundwater subsidence in the Santa Clara Valley. These charts persuasively illustrated the seriousness of the problem to the whole Santa Clara valley community and the need for water conservation. Supervisors and production managers are instructed to reduce water use where possible and posters obtained from the Santa Clara Valley Water District are on the cafeteria walls as additional reminders.

Results

Estimated water savings identified for the water conservation actions at AMD are as follows.

- Minor modification of the wafer fabrication rinse sinks reduced DIW from between 280 and 300 gpm down to between 180 and 200 gpm. This saves 80 to 120 gpm, which amounts to 154 to 231 ccf per day (115,000 to 173,000 gallons per day).

- Optimization of the DIW system reduced reverse osmosis reject rate from between 32 and 35 percent down to 29 percent. This drop represents a savings of up to 17 percent from the previous reject rate. Assuming a DIW usage rate of 200 gpm, the savings achieved is about 20 gpm, totaling 38 ccf per day (29,000 gallons per day).

Overall savings can be calculated from historical water use data over the last one and a half years. As shown in Figure 1, city water use in 1989 has been significantly reduced in each of the first six months when compared to 1988 use. This indicates that AMD has installed an effective and continuing water conservation program.

Total city water use for the first six months of 1989 are only 62 percent of that used by the same time in 1988. This savings is best illustrated by the cumulative year-to-date

usage graph shown on Figure 2. Average water use in 1988 for this period was 2,029 ccf per day, while the 1989 figure is 1,274 ccf per day. This represents a savings of 755 ccf per day or, if similar savings are projected for the remainder of the year, a total of 275,575 ccf (206 million gallons) of water for 1989.

Much of the savings can be attributed to the sink modifications which caused about 30 percent of the overall water use reduction. However, the significant portion of savings due to other measures shows that effective water conservation is an overall effort achieved by the summation of each conservation action.

Costs and Benefits

Costs associated with the process water changes at AMD are for capital expenses. Capital costs for the sink modifications at the wafer fabrication shop were about $50,000. Amortized over a design life of 20 years at 12 percent interest, the equivalent annual cost is about $6,700. There are no additional operating costs associated with this modification because the rinse system is automated. Since these are the only costs associated with water conservation which are documented, only the benefits directly associated with this measure will be taken into account in this cost-benefit analysis.

Reduced DIW use for wafer rinse of about 193 ccf per day accounts for an annual water savings of 70,445 ccf. At a current value of $1.25 per ccf, the annual cost savings for the water alone is over $88,000.

The annual savings calculated from the above costs are:

$/year = - ($/year savings due to lower water and sewer use fees)
+($/year increased operating costs and amortized capital costs for additional equipment)
= - $88,000 + 6,700

= - $81,300 per year, savings.

The conclusion, based on these cost figures, is that the modification of the DIW rinse sinks has been cost-effective. From the perspective of payback period for capital investment, based on the assumptions cited in this section, the simple payback period for initial capital investment is about 8 months. Not included in this analysis are the additional savings due to reduced wastewater disposal costs due to lower volume requiring disposal. Also, since less DIW is produced for wafer rinsing, operating costs for the reverse osmosis system are reduced. These factors make the conservation action even more cost-effective than indicated by looking only at direct costs and benefits.

Discussion

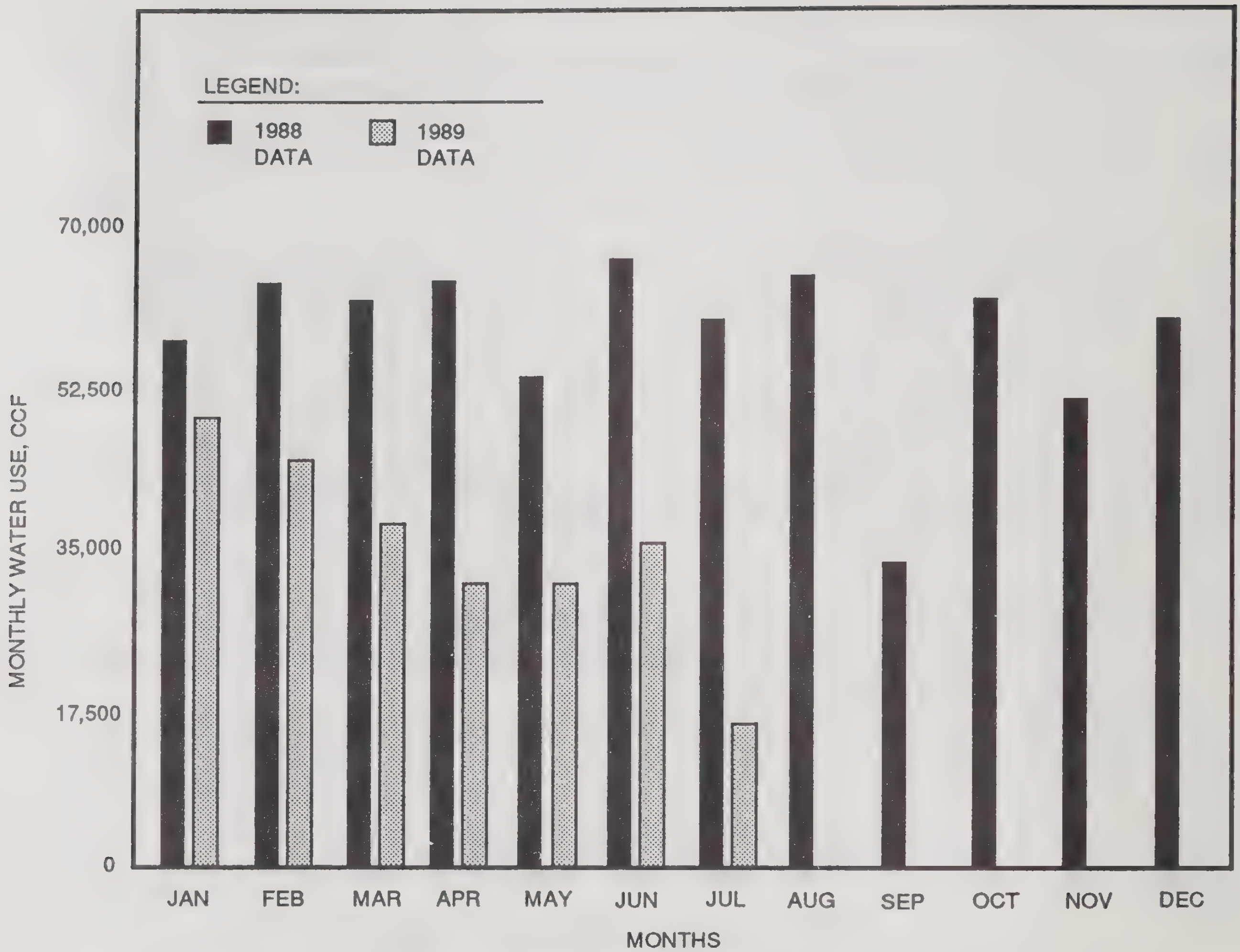
Water conservation at AMD has proven to be very successful, especially the modifications of the rinse sinks, as determined in the above cost analysis. Although the

modification of the wafer rinse system proved to be the most effective in saving water and money, AMD's other water conservation measures were important and successful as well. Overall water use has declined 62 percent from the previous year. Average water use in 1988 was 2,029 ccf per day, while the 1989 figure is 1,274 ccf per day, resulting in a projected annual savings of over 275,000 ccf of water. Modified water rinsing and R.O. optimization accounted for 72,000 ccf per year reductions.

The water conservation techniques used by AMD are applicable to a wide range of facilities, the main technique being the conversion of a constant flow system to a batch system. Although the AMD programmed batch rinse system seems sophisticated, the key elements of this type of water conservation are simple. Many systems which currently use a constant flow of water for rinsing can be converted to use water only when absolutely necessary. This method is similar to water conservation at home where we can save water by rinsing dirty dishes in a tub of water rather than leaving the water running. The key elements of this form of water conservation are:

1. Identify constant flow water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Determine whether the minimum water quality can be maintained using a batch system rather than a constant flow.
4. If practical, plan alternate equipment or/and operation to minimize water use.

Other water conservation techniques used at AMD are equally simple to employ. These include equipment or operational modifications for process water use, landscape irrigation reduction, and establishment and enforcement of reasonable water use practices.



		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CCF	1989	48,356	45,134	35,968	32,795	32,176	35,488	15,761	NA	NA	NA	NA	NA
	1988	58,553	63,828,	62,147	64,447	54,134	66,083	59,971	64, 782	33,622	62,781	50,340	59,388

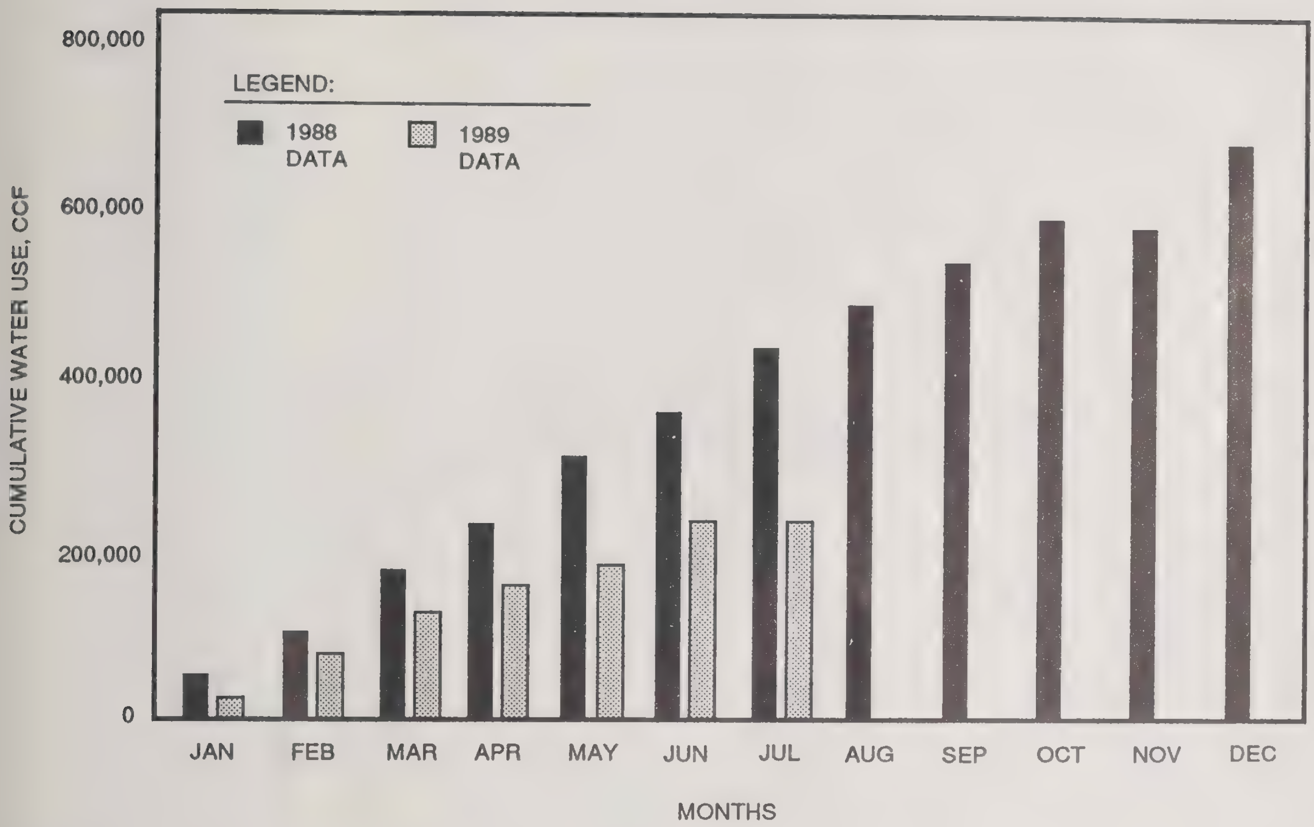
NOTES

All values are actuals (no adjustments).

Horizontal axis is months in the energy accounting year.

Each month's values are for that month only (not cumulative).

Figure 1 Monthly Water Use at AMD in 1988 and 1989



		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CCF	1989	48,356	93,490	129,458	162,253	194,429	229,917	245,678	NA	NA	NA	NA	NA
	1988	58,553	122,381	184,528	248,975	303,109	369,192	429,163	493,945	527,567	590,348	640,688	700,076

NOTES

All values are actuals (no adjustments).
Horizontal axis is months in the energy accounting year.
Each month's values are cumulative year-to-date as of that month.

Figure 2 Cumulative Water Use at AMD in 1988 and 1989

B.2

WATER CONSERVATION AT EXEL MICROELECTRONICS, INC.

Brown and Caldwell
January 11, 1990

WATER CONSERVATION AT
EXEL MICROELECTRONICS, INC.

Description of Facility and Business

Exel Microelectronics, Inc. (Exel) is located in an industrial park in North San Jose. Exel's business is manufacturing integrated circuits. The North San Jose facility is approximately 5 years old. The normal operating schedule at this facility is 24 hours per day, 7 days per week.

North San Jose is an area of particular concern for water conservation because of restrictions on Hetch-Hetchy source water during drought years, when a greater portion of the water supply is from local groundwater. This caused water quality concerns. Groundwater is harder and contains more dissolved solids than Hetch Hetchy water. Because Exel treats much of its manufacturing water to produce deionized water (DIW), higher hardness and dissolved solids would significantly impact water treatment costs. This examination led to changes, including a conservation program.

Major uses of water for manufacturing processes at Exel are:

1. Producing DIW by reverse osmosis (RO) of City water. The water consumption in this case is the production of a reject stream (brine) during the reverse osmosis process. Unless reused, the reject stream is lost to disposal.
2. Dip rinsing integrated circuit wafers in DIW.
3. Wet scrubbing of fumes.
4. Evaporative cooling for air conditioning and cooling equipment.

Exel also uses water in restrooms and for landscape irrigation, which are non-process water needs.

Description of Conservation Actions

Exel has instituted a number of water conservation programs. The more important are listed below:

1. Reducing the reject rate from the RO unit during production of DIW.
2. Reusing water RO reject for fume scrubbers.
3. Installing ozonation of recirculating cooling water, thus reduced blowdown.
4. Repairing DIW leaks.
5. Irrigating landscape at night.
6. Metering water use.

These programs are discussed in the following paragraphs.

Reducing RO Reject. Exel uses RO to produce 68,000 gallons per day (gpd) of DIW for rinsing integrated circuit wafers. RO is a membrane filtration process where water is forced through a semipermeable membrane which allows pure water to pass but rejects dissolved salts and organic compounds. Previously, 60 to 65 percent of the feedwater passed through the membrane as DIW. The remaining "reject" stream contains the dissolved compounds at a higher concentration.

One way to reduce water demand is to increase the "recovery rate" of the RO process; that is, pass a higher percentage of feedwater through the membrane and create less reject water. Exel optimized RO operation by changing to an improved acetate membrane. This caused the reject rate to decrease from 35 or 40 percent to 30 percent, saving about 11,000 gpd.

Reusing RO Reject. Whereas many RO operators dispose of the reject water, Exel reuses it in their fume scrubbers. A fume scrubber is a packed tower in which there is countercurrent flow of a contaminated air stream and a liquid stream. The liquid--in this case, RO reject--absorbs the contaminants in the air stream, purifying it for discharge to the atmosphere. The RO reject stream eliminates the need to use fresh water for fume scrubbing. In this application, Exel uses 7 to 10 gallons per minute (gpm) (12,000 gpd) of RO reject for scrubbing, reducing potable water demand by an equal amount.

Ozonating Cooling Water. Recirculating cooling water towers are used at Exel to recover heat from chillers. Exel conserves water by using ozonation rather than chemicals to treat recirculating cooling water. Installed in April 1988, the ozonation system has reduced blowdown, the removal of concentrated cooling water from the towers which must be replaced by fresh makeup water. Before ozonation, annual blowdown was 6.7 million gallons; after ozonation, it was 0.9 million gallons, an annual reduction of 5.8 million gallons.

Repairing Leaks. Exel estimates that the straightforward task of repairing leaks in the DIW system saves 130 gallons per day. Most leaks were associated with the bottom seals of the wet sink basins; other leaks occurred in the cooling system piping. The leaks actually totaled about 100 gallons per day. However, it takes about 130 gallons of feedwater to a RO unit to produce 100 gallons of DIW, the remaining 30 gallons forming the reject stream.

Watering Landscape at Night. Spray irrigation during the day promotes evaporation due to higher temperatures and wind. Therefore, Exel conserves water by switching to irrigating landscape at night.

Results

Table 1 summarizes the water savings resulting from the conservation measures. Total savings are 14.4 million gallons per year, with most savings from replacing the RO membrane, scrubbing with RO reject, and ozonating cooling water.

Costs and Benefits

Costs of implementing water conservation measures include capital and operating and maintenance costs. These costs are developed in the next section. The economic benefits of the conservation measures are then calculated. Table 2 summarizes the costs and benefits of the various conservation measures.

Costs. The new acetate RO membrane cost $47,000 and resulted in no additional operating and maintenance costs. Leak repair and reuse of RO reject water to scrub fumes incurred negligible costs. Capital costs for the cooling water ozonation system were $38,000, with annual operating and maintenance costs of $4,000.

Therefore, total capital investment for conservation measures was $85,000. Amortized over 20 years at 12 percent interest, the annual capital cost is $11,400. Adding the operating and maintenance costs, the total annual cost is $15,400.

Benefits. Costs savings are often based on avoided water and sewer fees and DIW production costs, assumed to be $2.30 and $10 per thousand gallons, respectively. The cost savings for replacing the RO membrane was calculated as follows:

$$
\begin{aligned}
\text{\$/yr} \quad = \quad & - (\text{\$/yr reduced water and sewer fees}) \\
& - (\text{\$/yr reduced DIW production costs}) \\
& + (\text{\$/yr cost to replace membrane}) \\
\hline
= \quad & - (\$2.30 \times 4{,}000 = -\$9{,}200) \\
& - (\$10 \times 4{,}000 = -\$40{,}000) \\
& + (\$6{,}300) \\
= \quad & - \$42{,}900\text{/yr, savings}
\end{aligned}
$$

Cost savings for scrubbing with RO reject were calculated similarly, assuming all avoided costs were water and sewer fees. Water savings from leak repair led to negligible savings.

Ozonation of cooling water incurred benefits from reduced labor, chemicals, and energy use, in addition to lower water use. Estimated annual savings from ozonation are tabulated in Table 3.

Table 1. Water Savings

Conservation Measures	Water Savings	
	Gallons per day	Million gallons per day
Replacing RO membrane	11,000	4.0
Scrubbing with RO reject	12,000	4.5
Ozonating cooling water	16,000	5.8
Repairing leaks	130	0.05
TOTAL	39,000	14.4

Table 2. Net Economic Benefits

Conservation Measure	Costs			Benefits		Net Benefits
	Capital, dollars	Annual operating and maintenance, dollars	Total annual cost, thousand dollars per year	Water savings, million gallons per year	Avoided costs, thousand dollars[b] per year	Benefits minus costs
Replacing RO membrane	47,000	--[a]	6.3	4.0	42.9	42.9
Scrubbing with RO reject	--[a]	--[a]	--[a]	4.5	10.3	10.3
Ozonating cooling water	38,000	4,000	9.1	5.8	30.3	21.2
Repairing leaks	--[a]	--[a]	--[a]	0.05	--[a]	--[a]
TOTAL	85,000	4,000	15.4	14.4	83.5	74.4

[a] Negligible cost or savings.

[b] All savings account for cost to implement conservation measures (column 4).

Table 3. Estimated Ozonation Cost Savings

Benefit	Annual Cost Savings, dollars per year
Reduced water use and blowdown discharge	13,800
Reduced chemical use	3,200
Reduced labor	11,000
Reduced energy use	11,400
TOTAL	39,400

Overall, water conservation measures save Exel about $83,500 per year. The payback period for capital investment was about 1 year.

Discussion

Exel approached water conservation in several ways, all of which are readily transferable to other integrated circuit manufacturers as well as a wide range of other industries. Key elements of each water conservation technique applied at Exel are presented below.

Process optimization, in terms of lower water consumption, must be done within the limits of equipment capability. Exel used this technique with RO operation. Elements are:

1. Identify major water uses.
2. Evaluate what process parameters affect water use.
3. Select equipment or operation procedures which minimize water use.

Reusing water (RO reject stream for fume scrubbing) is another technique, whose elements are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Plan alternative water sources.

A third water category was stopping leaks. This is a straightforward technique universally applicable.

B.3

WATER CONSERVATION AT HEWLETT-PACKARD CO.

Brown and Caldwell
February 7, 1990

WATER CONSERVATION AT HEWLETT-PACKARD CO.

Description of Facility and Business

Hewlett-Packard (HP) is an electronics company with production and research facilities throughout the United States and around the world, manufacturing over 6,000 product lines. This case study concerns the Hewlett-Packard Laboratories (HP Labs), a research and development facility in Palo Alto, California.

The water use of concern in this study is a deionized water (DIW) application for rinsing integrated circuit (IC) wafers. During processing, these wafers contact numerous chemicals, such as gases and dopants, various acids, oxidizers, alkaline solutions, organic solvents, and peroxides. Following many of the process steps, these wafers are rinsed using DIW. The rinsing operation is the point where significant water conservation has been implemented. DIW is reclaimed (recycled) by the system described below.

Description of Conservation Actions

Electronic wafers containing many individual IC chips are loaded vertically into a slotted plastic tray called a "boat." These boats transport the wafers step-by-step through the process. DIW is used to rinse the wafers following most of the process steps which apply solutions (for example, an acid/peroxide solution for etching). Boats are placed into a continuously flowing DIW rinse bath that may be agitated using nitrogen for more efficient scrubbing or rinsing. Most rinse bath stations on the wet bench have a valve assembly located in a gravity drain system beneath the wet process bench station that is controlled by automatic timer.

When the wafer boat first enters the rinse bath, the operator engages the timer to automatically divert the bath rinse water effluent to the acid waste treatment system. This carries away the most concentrated residuals (dragout) from the wafers. After about 90 plus seconds, the diversion assembly timers "Time Out" and switch the drain valves to deliver the flowing DIW to the Reclaim system (DIRC). Farther down the separate DIRC piping system, a resistivity monitor cell measures the quality of the DIRC water. When the resistivity reading is below a set point of 0.5 to 1.0 megohms-cm (too contaminated), it is diverted to the acid waste treatment system. Above the set point reading, the water is collected in a 1,200-gallon fiberglass reinforced plastic (FRP) storage tank prior to reclamation treatment.

The key concept relies upon recognizing that the first initial quantities of DIW used to rinse the wafers contain the heaviest amounts of contaminants. Whenever the total amount of DIW collected contains only small amounts of contaminants, it can result in requiring more work, because a larger volume of DIW has to be treated in order to reclaim it. Thus, if one tries to reclaim too much water, by cutting short the setting on the diversion timer, the operator will collect a smaller total volume over a 24-hour

period. Therefore, the timer must be allowed to divert the initial (most contaminated) DIW to waste for at least for 90 seconds up to 180 or 240 seconds in order to be able to maximize the total amount of reclaimed DIW. Experience has shown that only a very small amount of contaminant will lower the overall quality of a large volume of stored DIW. The amount of time required for rinsing is affected by the chemicals in a given rinse bath and many other factors. Some experimentation will be necessary initially with small adjustments required as the process changes. It should also be borne in mind that water usage in any research and development facility is extremely variable. At times, DIW usage at HP Labs may drop to only 10,000 to 15,000 gallons per day (gpd) required. This study shows what the savings would be if the facility operated at a constant use level of 34,000 gpd.

Description of the DIRC System

The DIRC is composed of a 1,200-gallon FRP storage tank, 70-gallon per minute (gpm) transfer pump, granular activated carbon (GAC) filter (containing 85 cubic feet of coconut-based GAC), 2.0-micron cartridge filters, and ultraviolet (UV) sterilizers. Water is collected by gravity feed into the tank, which empties on a transfer cycle controlled by liquid level controls in the storage tank. Upon a signal that the DIRC tank is full, a transfer pump automatically starts and transfers the reclaimed DIW through the GAC filter, cartridge filters, and UV sterilizers, back to the makeup reverse osmosis (RO) storage tank in the primary DIW loop at the front end of the DIW train. This DIW from the DIRC system is typically of better quality than the RO water entering the same tank.

Results

The DIRC was installed at the HP Labs facility in Palo Alto in 1975. Daily DIW demand would have been 54,000 gallons without a DIRC reclaim system. This would have required the installation of a 60,000-gpd RO system which, at a 70 percent recovery rate, would have had to treat about 75,000 gpd. Instead, a 30,000-gpd RO system was installed and the difference (24,000 gpd) was furnished by reuse of the same DIW after treatment with the GAC and UV system described above. Reclamation allowed recycling of up to 70 percent of the incoming RO makeup water.

Brine concentrate from operation of the RO system used in this case study is intermittently used as makeup to the exhaust fume scrubber and for irrigation. This practice has also been followed with favorable results at HP Santa Rosa and at HP's Stanford Park manufacturing site.

While this case study documents only DIW recycling at HP Labs in Palo Alto, HP requires design assessment of both new and existing systems regarding the feasibility of DIW reclamation on each project. For example, HP's Sunnyvale Printed Circuit facility also incorporates a separate DIRC system. This reclaim system incorporates a different design than the one in this study and has been used with favorable results in the manufacture of printed circuit boards since 1980.

Costs and Benefits

In 1975, the DIRC system increased the cost of the DIW system by less than 13 percent of the overall cost. Capital cost of the entire DIW system was \$154,000. Capital costs of the DIRC system, including piping, installation, and startup, was only about \$20,000. Amortized over a 20-year period at 12 percent interest, this correlates to an annual cost of \$2,700.

Operating costs--including GAC replacement (yearly), replacement filter cartridges, UV lamps, power, and labor--total \$9 per thousand gallons of DIW. (Costs to produce DIW from Palo Alto City water typically run about \$15 per thousand gallons.) Estimated water and sewer costs at Palo Alto are \$1.0 and \$1.3 per thousand gallons, respectively.

The annual savings for recycling DIW are determined using 1975 data; that is, a water use reduction of 24,000 gpd (recycled DIW) plus 10,000 gpd (brine concentrate water use for scrubber makeup and irrigation), totaling 34,000 gpd. The calculation is:

$$
\begin{aligned}
\$/\text{yr} \quad &= \quad - (\$/\text{yr lower water and sewer fees}) \\
&\quad\;\; - (\$/\text{yr lower DIW production costs}) \\
&\quad\;\; + (\$/\text{yr annual costs of DIRC system}) \\
\hline
&= \quad - (2.3 \times 34 \times 365) \\
&\quad\;\; - (15 \times 24 \times 365) \\
&\quad\;\; + ([9 \times 24 \times 365] + 2{,}700) \\
&= \quad -\$78{,}200/\text{yr.}
\end{aligned}
$$

Thus, water conservation saves about \$78,000 per year. The payback period in 1975 was only 3 months.

Discussion

Water conservation at the HP Labs facility has been quite successful over the years. This reclamation system allows up to 70 percent of the DIW to be recycled, currently reducing water use by over 34,000 gpd during periods of heaviest water usage. This resulted in substantial cost savings.

The reclamation/recycling technique is applicable to other electronics firms as well. Key elements of such a DIRC reclaim system are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for each use.
3. Evaluate the degradation of water quality resulting from each use.
4. Evaluate and manage the water treatment options for recycling the water.

B.4

WATER CONSERVATION AT INTEL CORPORATION

Brown and Caldwell
November 6, 1989

WATER CONSERVATION AT INTEL CORPORATION

Description of Facility and Business

Intel is a semiconductor manufacturer, with facilities in Santa Clara and San Jose, California, as well as other sites worldwide. This report addresses water conservation by the use of ozone to treat recirculating cooling water.

Description of Conservation Actions

Intel's application of this water conservation technique involved a pilot study in San Jose and a permanent installation at Building SC-4 in Santa Clara. The conservation potential of reducing cooling water waste is significant for a facility such as SC-4, where cooling loads for air conditioning and process equipment are high.

Recirculating cooling water in an evaporative system (cooling tower) presents a water conservation opportunity because the water usually needs frequent replacement in common multi-chemically treated systems. However, this water can be conserved by converting to an ozonated system.

In an evaporative cooling water system, the dissolved mineral salts present in the makeup water are increasingly concentrated during the process of evaporation. The residual, higher dissolved salt water of the cooling system requires treatment for three primary reasons: 1) to reduce the corrosion of all wetted metallic surfaces, 2) to prevent mineral scale build up, especially on the heat transfer surfaces, and 3) to reduce the bacterial and biological growth, which are the principal reasons for disease causing organisms found in the cooling systems. Corrosion, scale, and biological growth are traditionally combatted by adding a variety of chemicals and by periodically removing some of the recirculating water as blowdown and replacing it with cleaner, lower, dissolved salts concentration makeup water. The ratio of the concentration of dissolved salts in the blowdown to the concentration in the makeup water is called the cycles of concentration.

The higher the cycles of concentration, the lower the blowdown volume. Higher cycles of concentration can be achieved by using purer makeup water or by operating with higher mineral concentrations. The latter was done at Intel, where higher cycles of concentration have been shown to be achievable by replacing multi-chemical treatment with an ozone treatment system. Ozonation allowed successful cooling tower operation at much higher circulating mineral concentrations. As a result, converting from chemical treatment to ozonation conserved water at Intel.

Recent studies have indicated that ozone can achieve the three objectives of traditional chemical treatment while reducing the amount of water wasted in blowdown. In addition to water savings, other advantages are lower materials cost, energy savings, reduced labor requirements, and the reduction of cooling tower biological and chemical discharge risks.

Intel's motivation for using ozone rather than chemicals is a combination of water conservation and other anticipated benefits.

Intel's Approach

Ozonation of cooling tower water is a relatively new technology. Therefore, Intel pilot tested ozone treatment for one year (April 1984 to April 1985) at its San Jose facility, using a small, 60-ton cooling tower (where a "ton" of cooling is a heat rate, 12,000 Btu per hour). Table 1 presents the makeup water quality used in the test. Side-by-side comparison of ozone and chemical treatment indicated that ozone allowed higher cycles of concentration--and thus lower water loss to blowdown--while achieving better scale, bacteria, and corrosion control (see Table 2). The new ability to operate at 20 cycles of concentration is, compared with earlier two cycles, equivalent to using the water ten more times than before. The effects of scale fouling on heat exchanger efficiency are shown in Table 3. Ozone's performance in the pilot test is consistent with the conclusions of a 1979 Electric Power Research Institute (EPRI) study which noted that ozone treatment can be effective in small systems with relatively low temperatures and temperature differentials.[1]

Intel is now using ozone to treat cooling water at its SC-4 facility. The system consists of three cooling towers (two towers at 350 tons each, and one tower at 100 tons with a combined cooling capacity of 800 tons). The two big towers have a common basin, and the small one operates independently. The makeup water supply is similar to that of a pilot study (Table 1). At the present time, this water is softened to replace calcium and magnesium of the water, however, future studies will use unsoftened water. There is one ozone generator for all three towers. The system is fully automatic, and is monitored twice each day onsite as well as offsite through a telephone line.

This system was installed in August of 1989. During the initial four-month period of evaluation, the system confirmed previous experience with ozone systems. Although it is still too early to verify and confirm all data reported in the literature (References 2 through 5), water conservation results are promising. Prior to ozonation, the system was operating at two cycles of concentration. Now with ozonation, the system is operating at ten cycles. The future studies include zero blowdown with and without softened makeup water.

Costs and Benefits

Annual costs and benefits are estimated for the SC-4 ozonation system.[6] As shown in Table 4, ozone treatment is estimated to cost almost $29,000 annually, a savings of $20,000 per year over the estimated costs of chemical treatment for the same scenario. Intel obtained equipment on lease along with operating service including cleanout of sludge from the cooling tower. Because Intel did not directly incur the major capital cost, the best analysis of costs is on an annual basis. Although the financial impact of water savings is relatively small, the ozone system's use of an estimated 3.3 million

gallons less water per year than the chemical system has a significant benefit to the community's water resources.

Discussion

This case study is one of several in the City of San Jose Industrial Water Conservation Research Project where ozonation was successfully implemented for cooling tower water treatment. Water consumption was cut, and the technique was cost-effective. Similar facilities considering cooling tower ozonation should benefit from Intel's experience. Intel is willing to provide updates on its system water conservation performance to interested industrial facilities personnel.

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4. Baldwin, L.V., E.S. Feeney, and R. Blackwelder, "The Investigation and Application of Ozone for Cooling Water Treatment," NASA, presented at the 46th annual meeting of the International Water Conference, Pittsburg, PA, 1985.

5. Leitzke, O., K. Rohleder, and M. Murray, Ozone Treatment of Water for Cooling Applications, International Ozone Association, Inc., Vienna, VA, (1981). pp. 31-41.

6. Kazi, Abdullah. Personal Communication. July 1989.

Table 1. Makeup Water Quality for Intel Pilot Test[a]

Parameter	Concentration, ppm[b]
Total dissolved solids, (TDS)	435
Calcium	5
Magnesium	30
Sodium	97
Bicarbonate	29
Carbonate	20
Chloride	90
Nitrate	15
Sulfate	144
pH	8.7[c]

[a]San Jose city water, softened.
[b]Parts per million.
[c]pH is presented in tons of standard pH units.

Table 2. Pilot Study Results on a 60-Ton Cooling Tower

Parameter	Results: Chemical treatment	Results: Ozone treatment
Cycles of concentration	2	20
Blowdown TDS concentration, ppm	900	9,000
Bacterial growth, colonies per ml	>100,000	4,100
Corrosion, mils/year[a]	4 to 5	<1

[a]1 mil equals 0.001 inch

Table 3. Effect of Fouling on Energy Use

Fouling factor	Equivalent in inches of scale	Fouling condition	Percent increase in energy use
.0005	.006	Design clean	0.00
.0010	.012	Slight	5.50
.0015	.018	Moderate	11.0
.0020	.024	Heavy	16.5
.0025	.030	Severe	22.0

Reference: Grace Dearborn, "Effective Water and Energy Management," Journal of the American Institute of Plant Engineers. Vol. 14, No. 4, (1987) pp. 24-26.

Table 4. Cost/Benefit Analysis of SC4 Ozonation System

Operating expenses	Current, dollars	Ozone, dollars
Chemicals	6,166	0
Blowdown water	8,332	416
Energy costs (fouling)	18,537	10,500
Labor	4,658	0
Water softening	10,751	0
Ozonation equipment lease and service costs	0	17,952
Total annual costs	48,444	28,868
Total water saved	0	3.3 million gallons

B.5

WATER CONSERVATION AT INTERNATIONAL BUSINESS MACHINES CORP. (IBM)

Brown and Caldwell
December 20, 1989

WATER CONSERVATION AT INTERNATIONAL BUSINESS MACHINES CORP. (IBM)

Description of Facility and Business

At its General Products Division facility in south San Jose, IBM develops and manufactures data storage systems for use with its mainframe computers. The company occupies more than 4 million square feet of building space in 80 buildings at its 530-acre Cottle Road campus.

All of the water for the campus comes from IBM's deep and shallow groundwater wells. The deep wells produce good quality water, suitable for domestic and process use. The shallow wells produce a lower quality water. IBM currently uses about 300 million gallons of deep well water per year, 40 percent of which is used for process water. The remainder is used for irrigation and sanitary water. Shallow groundwater is used only for landscape irrigation. Industrial wastewater is pretreated, then discharged along with sanitary sewage to city sewers.

The normal operating schedule at this facility is 24 hours per day, 7 days per week. There are a total of 8,500 employees on various shifts on the campus site.

IBM's motivation to pursue water conservation was initially for its economical benefits. Reduced water use would lower wastewater fees, water costs, and taxes paid on groundwater pumping. However with the drought in the Santa Clara Valley, the emphasis has changed to acknowledge the necessity of saving water.

Description of Conservation Actions

IBM has conducted several studies on methods to conserve water at its San Jose facility. Through these studies and with the aid of employee suggestions and participation, several successful water conservation practices have been installed.

The major water conservation action at IBM is the treatment and reclamation of industrial wastewater. In 1983, IBM began reusing the effluent from its Industrial Wastewater Treatment (IWT) facility to provide cooling tower makeup at a 17,000-ton (one ton equals 12,000 Btu per hour) tower system, reducing the use of domestic well water for this purpose. The process diagram of this system is presented on Figure 1. The use of recycled process water had another side benefit in that it had a lower Total Dissolved Solids (TDS) content, 100 versus 400 parts per million, than the well water it replaced. This reduction in the cooling tower water TDS reduced blowdown requirements.

IWT effluent is also used for nonpotable service water for hosedown and water-sealed pumps at the IWT plant. This water-conserving feature was part of the original design of the IWT plant.

IBM modified the deionized water (DIW) controls, which reduced process use of DIW. Future plans include use of reclaimed IWT effluent at other cooling towers.

Landscape irrigation is a major water use at IBM. To reduce the amount of domestic well water used, IBM now uses lower quality shallow groundwater to provide much of its irrigation supply. IBM has also installed automatic timers on its sprinklers and turns them on only at night to reduce evaporation loss. Other landscaping alterations to conserve water include the filling in of water ponds with decorative gravel. IBM is also investigating the use of computerized irrigation control and landscaping with more native plants.

IBM has taken measures to reduce sanitary water consumption as well. Low-flow shower heads and low-flow aerators on sink faucets have been installed. Experimental use of low-flow toilets were unsuccessful; however, experiments on drilling out the orifice on urinals have produced shorter yet stronger flushes.

Other future plans for water conservation include conducting a domestic and DIW study to provide a mass balance and having IWT plant operators attend leak detection classes sponsored by the California Water Resources Commission.

<u>Results</u>

Estimated water savings identified for the water conservation actions at IBM are described below.

- IWT effluent replaces previously used fresh water as cooling tower makeup at a 17,000-ton cooling tower system. Of the total 91 million gallons per year (MG/yr) used at this tower system, 80 MG/yr is IWT effluent, reducing freshwater needs by an equivalent amount. (The current IWT flow rate is up from the 25-MG/yr rate of 1983, when this conservation measure was first adopted at IBM.)

- Because IWT effluent is higher quality than domestic well water (400 ppm TDS versus 100 ppm), less blowdown is required to maintain recirculating cooling water quality. Blowdown was reduced by over 13 MG/yr as a result of using IWT effluent for cooling. When evaporation and drift are considered, total reductions in makeup water requirements exceeded 20 MG/yr.

  Summarizing cooling water conservation results, the 17,000-ton cooling tower system previously required 111,000 MG/yr. By using higher quality IWT effluent, the rate dropped to 91 MG/yr, of which only 11 MG/yr is freshwater. Total reduction in freshwater use is therefore 100 MG/yr.

- Modified controls on the DIW water system save 900,000 gallons per year.

No historical data were provided for water use prior to start up of conservation actions. Therefore, it is difficult to determine an overall percentage water savings.

Costs and Benefits

Due to limited data on cost and water use, this section will only analyze the results of actions associated with reclaiming IWT effluent at IBM. Costs associated with this action are for capital and operating expenses. However, the major equipment changes causing the most significant water savings were planned separately from water conservation. Therefore, the capital investment for the IWT plant itself is not included in this analysis.

An indication of the economy of reclaiming IWT effluent at IBM can be gathered from knowledge of local water supply and sewer fees, and estimates of capital and operating costs. Capital costs solely for water conservation--for process alterations and pumping the IWT effluent--are estimated to be less than $50,000. Amortized over a design life of 20 years at 12 percent interest rate, the equivalent annual cost is about $6,700.

Operating expenses for materials dropped as a result of reclaiming IWT effluent. Less chemicals are needed for conditioning the lower-TDS reclaimed water. Additional operating costs for recycling actions are for labor to monitor and maintain the equipment and power. The overall operating costs are estimated to have increased $10,000 per year due to IWT effluent reuse. Thus, the combined capital and operating costs for reclaiming IBM's IWT effluent is about $16,700 per year.

Water supply and sewer service costs are essentially variable in proportion to water volume. The cost for well water, which includes depreciation, maintenance, power and well pump tax, is estimated to be about $0.40 per thousand gallons. Estimated wastewater disposal costs are approximately $1.30 per thousand gallons. These unit costs are summed and multiplied times the total reclaimed flow because that flow substitutes for an equal amount that would be used otherwise.

The annual savings for reclaiming IWT effluent calculated from the above costs are:

$/year = - ($/year savings due to lower water and sewer use fees)
+($/year increased operating costs and amortized capital costs for additional equipment

= - $170,000 + $16,700
= - $153,300 per year, savings.

The conclusion, based on these cost figures, is that the water conservation due to IWT effluent reclamation was cost-effective. From the perspective of payback period for capital investment, based on the assumptions cited in this section, the simple payback period for initial capital investment is less than 4 months.

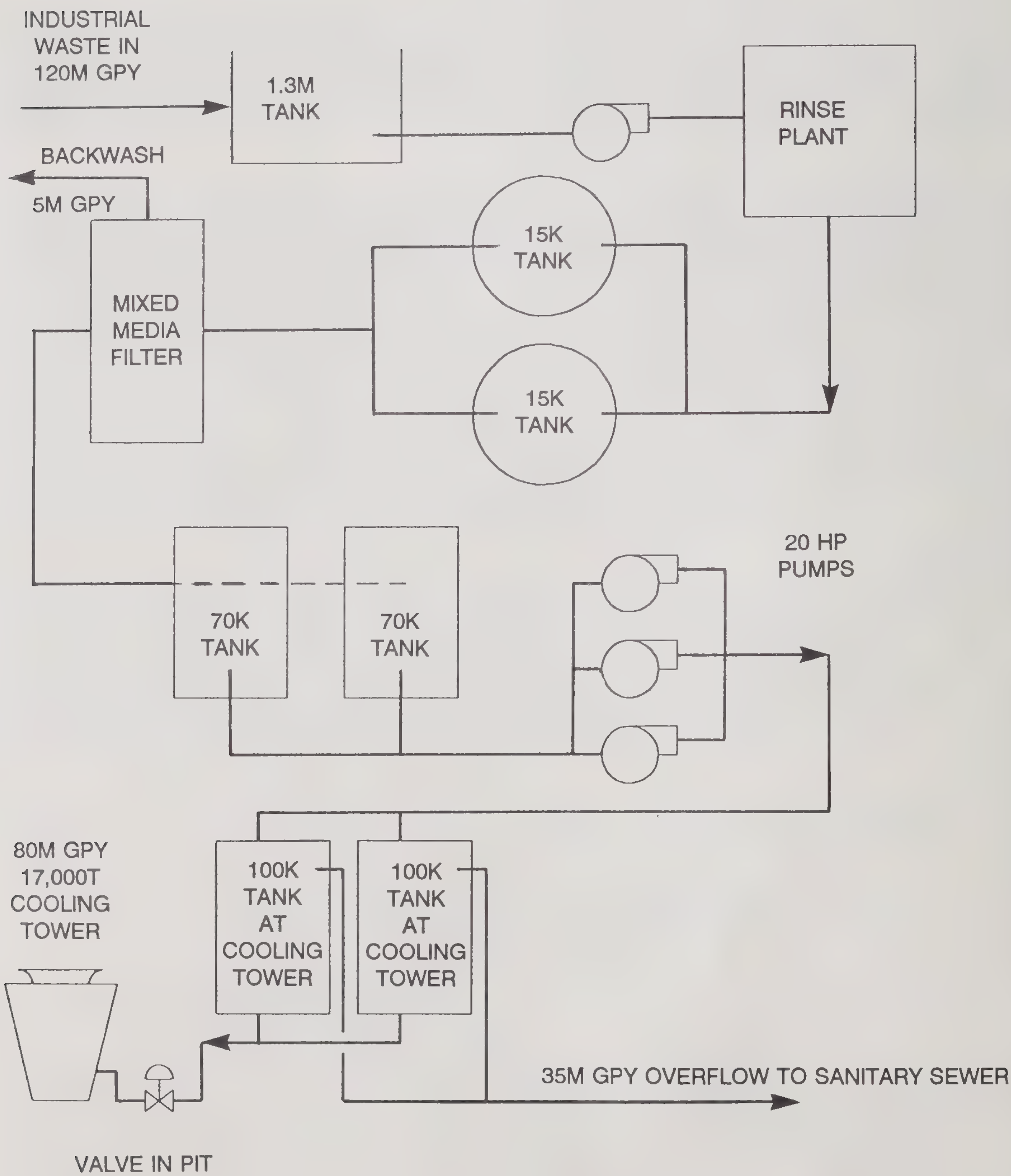
Discussion

Water conservation at IBM in San Jose was very successful. The single action of reclaiming its wastewater effluent has reduced IBM's domestic well water use by 100 MG/yr and provided a substantial cost savings.

Water conservation techniques used at IBM are applicable to other high-tech firms as well as a wide range of other industries. The key water conservation technique used at IBM was reuse. Reusing water must be done within limits of required water quality. Elements of this water conservation technique are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Evaluate the degradation of water quality resulting from use in this and other processes.
4. Evaluate whether this water can be recycled for use in the same process or from other processes with minimal treatment.

Figure 1. IBM Industrial Waste Treatment Process



B.6

WATER CONSERVATION AT INTERNATIONAL MICROELECTRONIC PRODUCTS

Brown and Caldwell
August 23, 1989

WATER CONSERVATION AT
INTERNATIONAL MICROELECTRONIC PRODUCTS

Description of Facility and Business

International Microelectronic Products (IMP) is located in an industrial park in North San Jose, an area of particular concern for water conservation because of restrictions on Hetch-Hetchy source water.

IMP's business is the manufacture of integrated circuits (ICs). Major uses of water in the manufacturing process at IMP are dip rinsing of IC wafers in deionized water (DIW), wet scrubbing of fumes, and cooling of equipment. A notable non-process water use is service to restrooms.

The normal operating schedule at this facility is 24 hours per day, 7 days per week.

Concerns about water quality problems and water allocation motivated IMP personnel to pursue water conservation. Water quality concerns arose from the increased portion of groundwater in the water supply to North San Jose. Because a major proportion of water used at IMP is DIW, higher water hardness and dissolved solids would increase water usage, water treatment costs, and the risk of contamination in ultra-clean manufacturing. Water allocation presented a potential obstacle to company growth at this site. This examination led to changes, including a conservation program.

Description of Conservation Actions

The major water conservation action at IMP has been reduction in use of DIW rinsewater. Also, reject water from the reverse osmosis (R.O.) DIW production process is reused in non-potable applications. Another change is conversion to a closed loop cooling water system. A fourth water conservation action at IMP has been a water use monitoring program.

Conservation of DIW at IMP was accomplished by installation of new equipment in the IC fabrication area. This equipment change was at the 15 wet sink rinse stations. Boats of IC wafers that have contacted acid are rinsed by dipping in DIW sinks. In the new equipment, DIW flows only when wafer boats are being dipped. These stations use DIW at flow rates of 0.5 to 3 gpm. These relatively small flows add up to significant water savings when summed for multiple stations and over long operating periods.

Additionally, DIW conservation has an amplified benefit because DIW production typically requires 30 to 50 percent more total water than the volume of DIW produced. This extra water is the reject water from the R.O. unit used to produce DIW. The quantity of reject water expressed as a percentage of the feed to the R.O. unit is the reject rate. This is typically 25 to 35 percent of the feed. R.O. reject water serves the purpose of carrying away concentrated dissolved and suspended solids which were present in the City water supply. It does not, however contain added material.

Therefore, R.O. reject water is useful for applications which do not need as high quality water as the City water supply. Previously, R.O. reject water was discharged.

At IMP, R.O. reject water is reused for non-potable applications. This reuse has conserved the fresh water supply that was previously used for those non-potable applications. This conservation action required additional equipment: a collection tank, pump, and a piping system with backflow preventers to carry this water to the non-potable use points. The main application of non-potable reuse at IMP is for toilet flushing. Other non-potable uses of reject water at IMP are for aspirating used acid solutions out of process sinks, and as makeup to a cooling tower and a fume scrubber.

Water quality is not important for the first two R.O. reject reuse applications because they are merely for carriage of wastes. They do not require the high quality of water supplied as potable water, and therefore will not be affected by the use of R.O. reject water. The latter applications involve evaporation from circulating streams passing through towers, and in the case of the cooling tower, the water also passes through a heat exchanger (a chiller). The higher concentrations of minerals in R.O. reject water are of concern in these applications because of the increased possibility of scaling (deposition of minerals) and corrosion. Careful monitoring, operation, and selection of materials are important in such reuse applications.

Equipment cooling at IMP was previously accomplished with one-time use of fresh water. This equipment was connected to a closed-loop chilling system, thus greatly reducing the consumption of water.

In addition to these process changes, IMP has implemented a monitoring program in which daily readings of the water meter are recorded. Comparison of daily water use with past flow rates provides a tool for quickly discovering hidden water waste, such as leaks.

<u>Results</u>

Estimated water savings from water conservation actions are as follows.

- Reduced DIW use in the wet sinks in the IC fabrication area is estimated to have saved 30,000 gpd of DIW. Including the R.O. reject generated in producing this DIW, the savings of fresh water have been about 40,000 gpd. This change was implemented June 20, 1988.

- Non-potable use of R.O. reject water, primarily in the restrooms for toilet flushing, has saved an estimated 3,000 to 4,000 gpd. These reuses were begun in August, September, and October of 1988.

- Cooling equipment with circulating chilled water ended consumption of a large flow of fresh water previously used once then discarded. This savings is estimated to be 5,000 to 7,000 gpd.

- Daily monitoring safeguards against water waste. In one case, a 30,000 gpd leak was quickly discovered.

Figure 1 shows water consumption at IMP in thousands of gallons per day over the period before and after the water conservation actions described above were made. Comparing the periods of August to June 1987-88 with July to January 1988-89 indicates a sustained drop in water consumption of about 50,000 gpd. This is a 25 percent reduction in total water usage.

The demonstrated 25 percent lower water consumption underrates the water conservation success at IMP because during this period IMP has steadily expanded manufacturing production. Water consumption relative to manufacturing production is a more valid measure of the effect of water conservation actions. Figure 2 shows water usage per production unit. These data are normalized to hide actual production figures. The effect of water conservation at IMP's facility between the August to February periods of 1987-88 and 1988-89 is a 45 percent reduction in water usage per manufactured unit.

Awareness of the need to conserve water at IMP and daily monitoring of water usage have also contributed to the successful reduction in water consumption. Proof of the value of daily monitoring occurred August 15, 1988, when an elevated water flow was traced to a hidden open valve that had lost 30,000 gallons in one day. This loss may not have been detected otherwise.

Costs and Benefits

Costs associated with the process water changes at IMP are for capital and operating expenses. However, the major equipment changes causing the most significant water savings were planned separately from water conservation. This capital investment, in replacing wet sinks in the IC fabrication area, cost $500,000. Capital costs solely for water conservation--for reuse of R.O. reject for non-potable use and the conversion to closed loop cooling--are estimated to be less than $50,000. Operating costs added for water conservation actions are for labor for reading the water meter daily and for maintenance of additional equipment. These marginal added operating costs are estimated to total less than $10,000 per year.

An indication of the economy of water volume reduction actions at IMP can be gathered from knowledge of water supply and sewer fees, and estimates of operating costs. Combined costs of water supply and sewer service in North San Jose are essentially variable in proportion to water volume--about $0.003 per gallon. About one third of this cost is for water supply. The other two thirds is for wastewater handling, treatment, and sewer fees. Figures on water treatment costs are estimated from a typical microelectronics industry cost for DIW production of $0.010 to $0.015 per gallon. The estimated water savings of 30,000 gallons of DIW per day thus translates to a savings of

about $500 per day. The cost savings due to other water conservation actions are due to avoided water and sewer fees, and are calculated to total $30 per day.

The annual savings calculated from the above costs, but not including capital costs, is:

$/year =	- ($/day savings due to reuse and closed loop cooling) x 365
	- ($/day savings due to DIW conservation) x 365
	+($/year for added operating costs)
=	- $11,000 - $180,000 + $10,000
=	- $181,000 per year, savings.

Compare this estimated annual savings with the initial capital investment for water conservation, which is estimated to be less than $50,000. The annual cost of this investment is less than $7,000 when amortized. The amortization basis used here is 12 percent interest rate over a 20 year design life--the same basis used in analysis of other case studies in this project--and is not necessarily the period for which this equipment will be used. Net annual savings for water conservation at IMP if only the intentional water conservation investment costs are included is thus greater than $174,000 per year. The capital cost recovery period on this basis is 3.3 months.

The costs and benefits for water conservation at IMP may be compared in other ways. If the costs and savings for water conservation not including the DIW conservation are compared, the estimated net savings is $11,000 - $10,000 - $7,000 = -$6,000. This is a net annual cost, suggesting that these measure are not cost effective. Such is the case if capital costs were as high as $50,000 and annual marginal added operating costs are $10,000. These estimates are maximums. Net savings is very sensitive to these costs. If these costs were controlled to 70% of these estimates, then the non-DIW measures would break even economically.

If all the costs, including the $500,000 investment in new wet sinks, are compared with the savings due to lowered water use, then there is still an overall savings. The total estimated capital investment, $550,000, is equivalent to an amortized annual cost of $74,000. Net savings including amortized capital are $181,000 - $74,000 = $107,000 per year. Alternatively, the simple capital cost payback period is 3.0 years.

The conclusion, based on these cost figures, is that the water conservation at IMP was cost-effective, mainly because of the decrease in DIW treatment costs.

<u>Discussion</u>

Water conservation at the IMP manufacturing facility in North San Jose was very successful. A 25-percent reduction in total water usage was achieved. This was during a period of increasing production. Water usage per manufactured unit was reduced 45 percent.

The water conservation techniques successfully used by IMP are applicable to a wide range of industries. The key principle applied at IMP is that of retrofitting equipment to use less water. Elements of this water conservation technique are:

1. Identify major water uses.
2. Evaluate the minimum water quantity and or quality needed for these uses.
3. Change equipment, operation, or water source.

Another water conservation technique demonstrated successfully at IMP is close monitoring of water usage. Elements of this technique are:

1. Set up a regular (daily is good) recording program for water usage.
2. Evaluate water consumption in comparison to normal rates and with consideration to plant production.

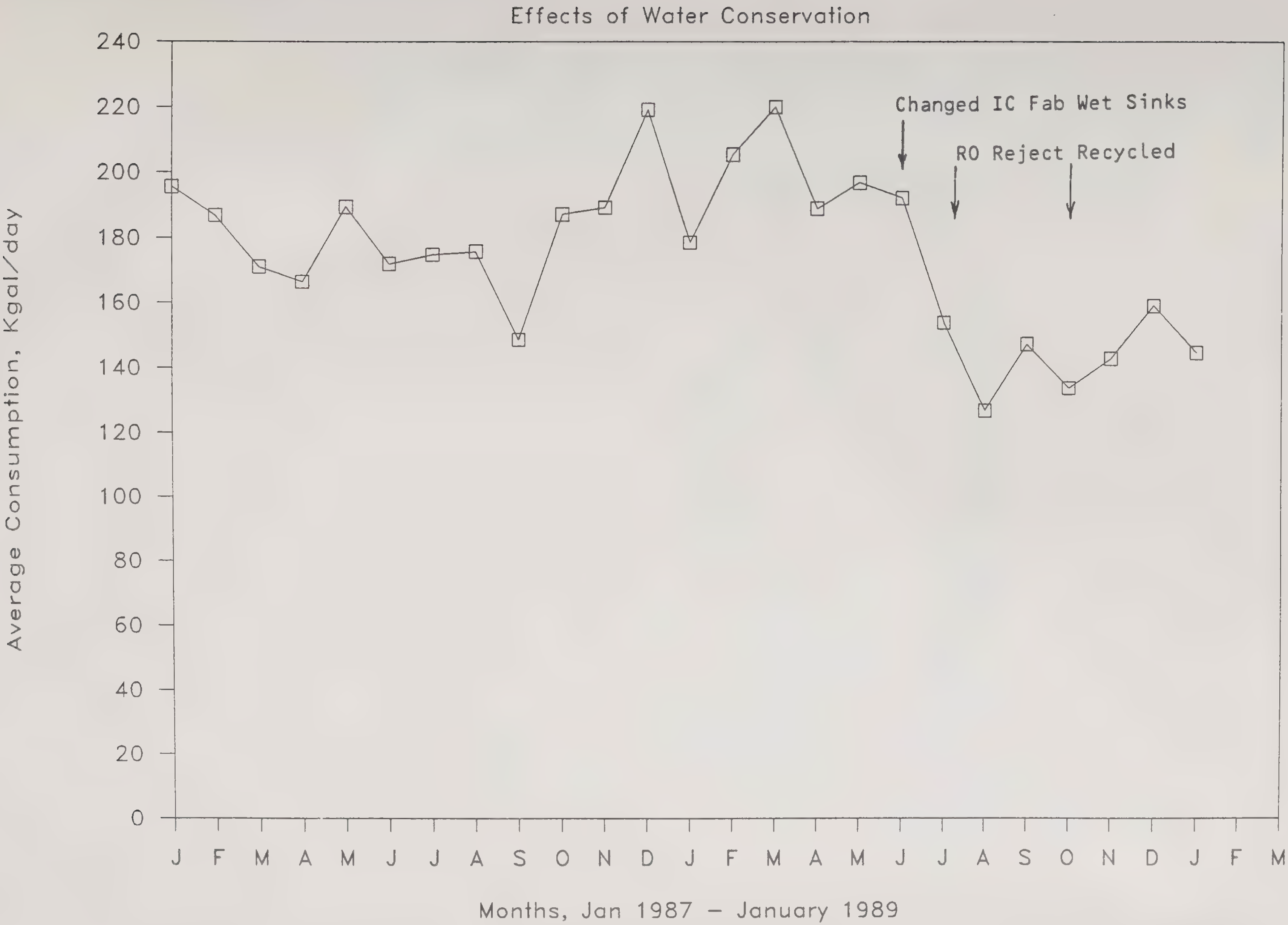
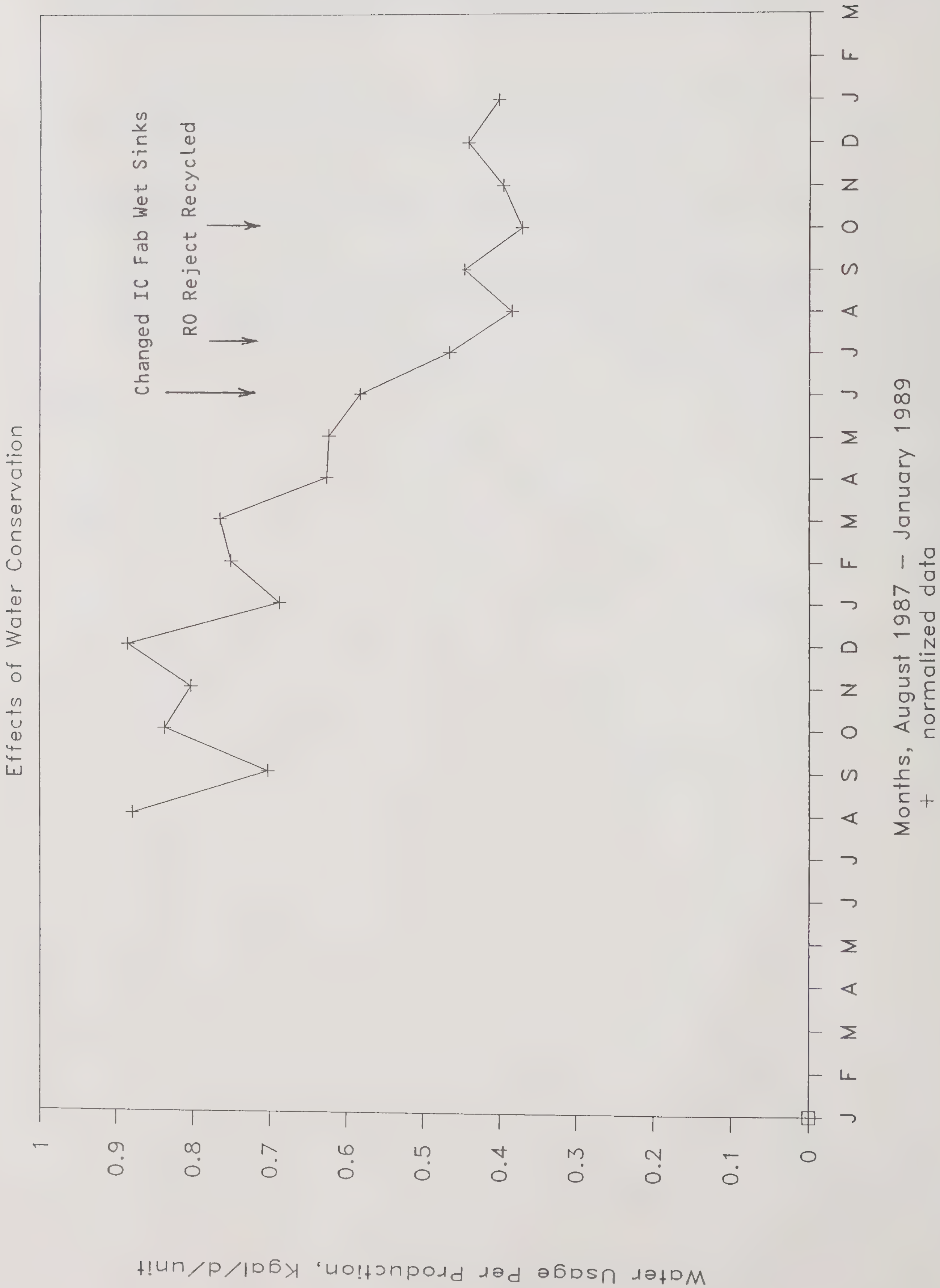


Figure 1. Water Usage at IMP

Figure 2. Water Usage at IMP



B.7

WATER CONSERVATION AT NATIONAL SEMICONDUCTOR CORPORATION

Brown and Caldwell

January 12, 1990

WATER CONSERVATION AT NATIONAL SEMICONDUCTOR CORPORATION

Description of Facility and Business

National Semiconductor's Santa Clara Facility is an industrial and office campus comprising over 39 buildings. It is located on the border with Sunnyvale. Water is obtained mainly from an on-site well belonging to the City of Santa Clara Water Department.

National Semiconductor's business is the manufacture of integrated circuits (IC) and other electronics products. A metal finishing facility at the same campus--Dyna-Craft, Incorporated--is the subject of a separate water conservation case study report in this project.

Most water used at this facility is deionized water (DIW) for rinsing during manufacturing processes. Large volumes of pure water are needed for manufacturing microelectronic products. Other uses of water at this facility are landscape irrigation, evaporative cooling of equipment, wet scrubbing of fumes, and restrooms. Figure 1 presents the breakdown of the water use at this facility, showing that about 70 percent of water use is DIW rinsing.

Three sources of motivation were behind the effort to conserve water at National Semiconductor's Santa Clara Facility. These were:

1. Mandated reduction in water use by 25 percent from 1987 consumption levels.
2. Economically, the cost of water was significant. The charge rate was increased by 37 percent.
3. Wastewater reductions which result from lowered water use were being investigated by the San Jose/Santa Clara water pollution control plant to defer construction expanding the capacity of the wastewater treatment plant.

Description of Conservation Actions

As part of their facilities design and operation, national Semiconductor has long considered water conservation. In 1988 and 1989, Facilities and Environmental Protection personnel at National Semiconductor undertook a planned program of water conservation. This program consisted of:

1. Collection of data on water use. Daily meter readings of water intake for major uses were instituted.

2. Prioritization. Effort was concentrated on the large water flows, but with consideration for small flows if wasteful practices were found.

3. Action. A detailed review of water use was done for the major flow sector--DIW in the manufacturing processes. Opportunities for water conservation were identified, evaluated, scheduled, and implemented.

4. Follow up, consisting of: a) weekly progress meetings of all personnel with the plant manager, b) assignment of water use auditors for various areas, and c) monthly meetings of key water conservation personnel to report on continued or additional water conservation.

Deionized Water Conservation. The major water conservation actions at National Semiconductor have concerned the use of DIW. Two major techniques have been applied. The first, instituted prior to 1988, was reclamation and reuse of DIW rinse water from production areas. This technique was a design modification of the facility DIW system which recovered some of the DIW rinse streams and returned that water to the DIW treatment system. Quantified water savings are presented in the Results section.

The second DIW conservation technique has been improving operation of the equipment that uses DIW for rinsing IC wafers. These are sinks, termed "wet-decks," for rinsing chemicals (primarily acids) from the wafers. A rack, or "boat," of wafers is immersed in DIW at the wet decks. To carry away the acid-contaminated DIW, water is drained from the sinks. This facility has over 300 wet decks.

Wet-deck changes involved a detailed review of the design and operation of the wet decks. A coordination group made lists of the equipment and water use at each wet deck. In a survey and repair inspection, each piece of equipment was inspected and the existence and condition of various functions noted on a standard checklist. Leaks were repaired immediately. Use of small, constant, uncontrolled flows for rinsing (trickle flows) were eliminated. Operational changes to reduce water usage in the wet decks were then evaluated.

Changes were based on technical evaluations for optimizing the operation. Previously, after immersion of wafer boats, there followed a plenum flush (around the edge of the sinks). The project engineer found that the plenum flush was not needed to maintain adequate water quality for the next rinse, so this function was eliminated. Second, the flow rate for dump rinsing was measured and often found to often be above the optimum--by about 1 gallon per minute (gpm). Third, the number of rinse cycles in dump rinsing and the length of those cycles were optimized. Previously, up to 16 rinse cycles were used. This provided extremely thorough rinsing, in the pursuit of protection against wafer contamination. However, too many rinse cycles were being used. Two to six rinses were used after the change. Also, the length of rinse was usually found to be too long. It was reduced to an optimum 1.5 to 2.0 minutes from up to 10 minutes used previously.

Reclaiming Water for Scrubbers and Cooling Towers. Water is reclaimed from acid rinses and used in air conditioning system cooling towers, process equipment cooling towers, EPI scrubbers, and fume scrubbers. Scrubbers are large chambers in which exhaust from manufacturing areas, sometimes containing chemical fumes, is contacted with a circulating flow of water sprayed into the chamber. The fumes are absorbed into the water. This reclamation uses on-line water quality monitoring for the parameters total organic carbon (TOC), total dissolved solids (TDS), and pH.

Water is also reclaimed from a groundwater cleanup project for use in scrubbing and cooling towers. The groundwater reclamation project is not considered in this water conservation case study.

Other Water Conservation Techniques. In addition to these process changes, National Semiconductor has applied an employee awareness program and an irrigation water conservation effort. In the restrooms, stickers asking employees to help conserve water were placed. Also, the names and numbers were provided for two people to contact regarding water conservation or to report leaks.

Landscape irrigation accounts for only 7.5 percent of the total water use at this facility. This use is visible, though, and any water waste by the sprinkling system has symbolic impact in addition to the actual loss of water. An evaluation was done of how irrigation use could be reduced. A notable action was cutting the sprinkling of paved areas adjacent to landscaped area by turning off all perimeter sprinklers.

Results

Figure 2 displays water use at the Santa Clara Facility. From January 1987 through June 1988, data are available for total use, DIW only, and non-DIW use. DIW use accounts for about 70 percent of total water use, supporting the breakdown on Figure 1. Total water use data are available through October 1989. Note the decreasing trend, even in traditionally high-use summer months.

The first water conservation technique involving DIW is a feature built into the system--recovery and recycle of a portion of the DIW used for rinsing. In 1987, the recycled flow was equal to 46 percent of the average total DIW produced. Since about 72 percent of the total 1.8 million gallons per day (mgd) average water use for 1987 was for DIW (see Figure 2), the savings represented by the recycle of DIW for 1987 was about 0.6 mgd, or 800 hundred cubic feet (ccf) per day. On a monthly basis, these flow savings are 18 million gallons per month, which equals 24,000 ccf per month.

The second water conservation technique involving DIW was improvement of the wet-decks operation and maintenance. An estimated 50 percent of the total water savings at the facility is attributable to this action. This water savings is about 15 million gallons per month, or 20,000 ccf per month.

Total water savings between 1988 and 1989, the period during which the wet deck improvement program was pursued, dropped by 1 mgd (1,300 ccf/day) for weekday operation, from 1.8 mgd to 0.8 mgd. This is a 55-percent reduction. This figure is confirmed by a similar reduction in wastewater volume, as shown on Figure 3. The period covered by this data overlaps the period shown on Figure 2 for water consumption. Baseline water consumption averaging 1.8 mgd, or 2,400 ccf per day, compares to wastewater flow rates in a ratio that is typical of manufacturing facilities like this, which have neither incorporation of water into products nor major evaporative water loss. This ratio is about 90 to 95 percent of intake volume passing to wastewater. In summary, the total estimated water savings between 1988 and 1989 is 30 to 40 million gallons per month, or 40,000 to 50,000 ccf per month.

Reclamation of water involves reusing acid rinse water for scrubbers and cooling towers. The acid rinse water reclamation has an estimated water savings of 5 to 10 million gallons per month (6,500 to 13,000 ccf per month).

Nonprocess water conservation at National Semiconductor consists of employee awareness programs and lowered irrigation flows. The awareness program impacts a wide variety of water uses, ranging from restrooms to floor washdown. These miscellaneous uses are expected to have also reduced water consumption, but are not quantified. The maximum scope of their impact can be illustrated, though, by the proportion of total water use occurring in affected categories. Three water use categories at the National Semiconductor facility that are most subject to improvement by general employee awareness programs have the following percentages of total water use: restroom use, 3.8 percent; miscellaneous industrial use, 3.8 percent; and cafeteria water use, 1.9 percent.

Results of landscape irrigation water conservation at the National Semiconductor industrial campus can be illustrated by the water use at the adjacent company-owned park, which is actually over the border in Sunnyvale. Comparison of water use for the same seasons where data were available--the months April, May, and June 1987 with those for 1988--show a reduction from 127,000 to 73,000 gallons per day. This is a 43 percent reduction. Actual irrigation water savings would depend on the relative weather for these periods, since irrigation demand is weather dependent. At this site it varies by a factor of 6 between the wet season and dry season, and will be influenced significantly by weather differences between the same months in different years.

Costs

Costs associated with the process water changes at National Semiconductor, where available, are in the form of summary figures. The first water conservation technique--the DIW system's recycle feature--preceded the time for which cost information is available, so a cost-benefit comparison cannot be made. The other DIW conservation program--for wet deck review and improvement--required no new technology or equipment. Costs centered on labor of an engineer and technician to lead the program. The water saved by this program, 15 million gallons (20,000 ccf) per month, has a benefit

of $110,000 to $260,000 per month. This is based on $0.78 per ccf for avoided water purchase, plus $0.94 per ccf for avoided wastewater charges, and $0.005 to $0.015 per gallon avoided DIW treatment costs. A conservative estimate of the costs for implementing the program is $10,000 per month. Therefore, the program had a payback in its first month. Subsequent months would provide greater benefit to cost ratio, since water savings are sustained, but costs are lower for program follow-up.

The acid rinse water reclamation for scrubbers and cooling towers had replumbing and considerable water quality monitoring equipment. The capital costs were $120,000. The cost recovery period was only 6 months.

Discussion

The water conservation program and techniques successfully used by National Semiconductor at their Santa Clara Facility are applicable to a wide range of industries. First, the program will be discussed, then the techniques.

The key factor cited in the success of the 1988/89 water conservation program was that the program was set as a priority by company management. A senior vice president met with the utilities manager at the beginning of the program, and established a commitment to cut water consumption. A facilities engineer with long experience and a technician were assigned to the program. Post program evaluation concluded that this commitment of time and technical expertise was vital for achieving this level of success.

Another important factor in the program's success was communication. Weekly meetings were conducted, with responsibilities assigned for specific tasks. Individuals' efforts were recognized and thanked. Also, in the more traditional manner of water conservation programs, promotional materials such as signs and stickers were used in the employee awareness campaign. The third factor cited as contributing to the success of the program was the quality of technical approach. Data collection, prioritization, and effective, appropriate technical solutions were vital.

Most of the water saved at National Semiconductor's Santa Clara Facility was by various forms of recycling. The first technique used was recovery of DIW rinse water to the DIW production system. This cut the amount of freshwater feed. The elements of this type of recycle are:

1. Evaluate the degradation of water quality occurring by various uses of treated water.
2. Compare this water quality with that of the untreated water used as feed to the treatment system.
3. Balancing concerns for contamination protection, treatment costs, and relative flow rates, recycle some of the used water to the treatment system.

The second technique of DIW conservation centered on operation and maintenance. Elements of this technique are:

1. Identify equipment using large water quantities. Prioritize the effort on the major water uses.
2. Survey the equipment's water uses and condition.
3. Evaluate water savings achievable and the means to do so by analyzing what the optimum water use is for the operation.
4. Conduct a modification and/or repair program.
5. Follow up to confirm program execution. Establish a preventative maintenance program.

The third technique of water conservation at this facility was reclamation of former wastewater. Elements of this type of recycle are:

1. Identify wastewater streams that have water quantity that is relatively high and quality that is sufficiently good that reuse may be feasible.
2. Identify current water uses which use water of higher quality than is necessary. An example is using fresh City water for cooling towers and scrubbers.
3. Evaluate the water quality needed. Compare this water quality with that of available wastewater streams.
4. Connect the sources with uses where appropriate. Include treatment where needed and feasible and, usually, cost effective.

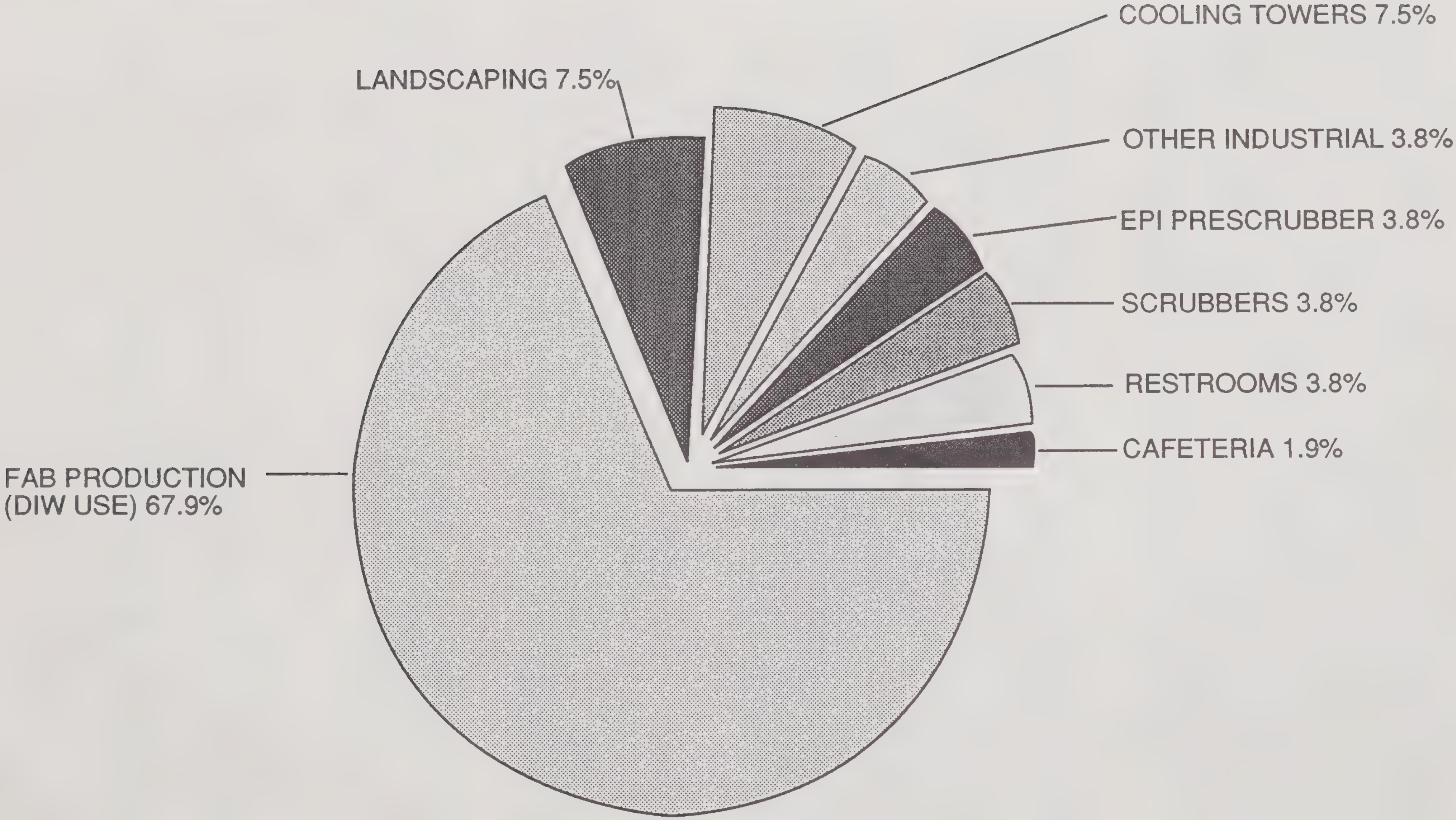
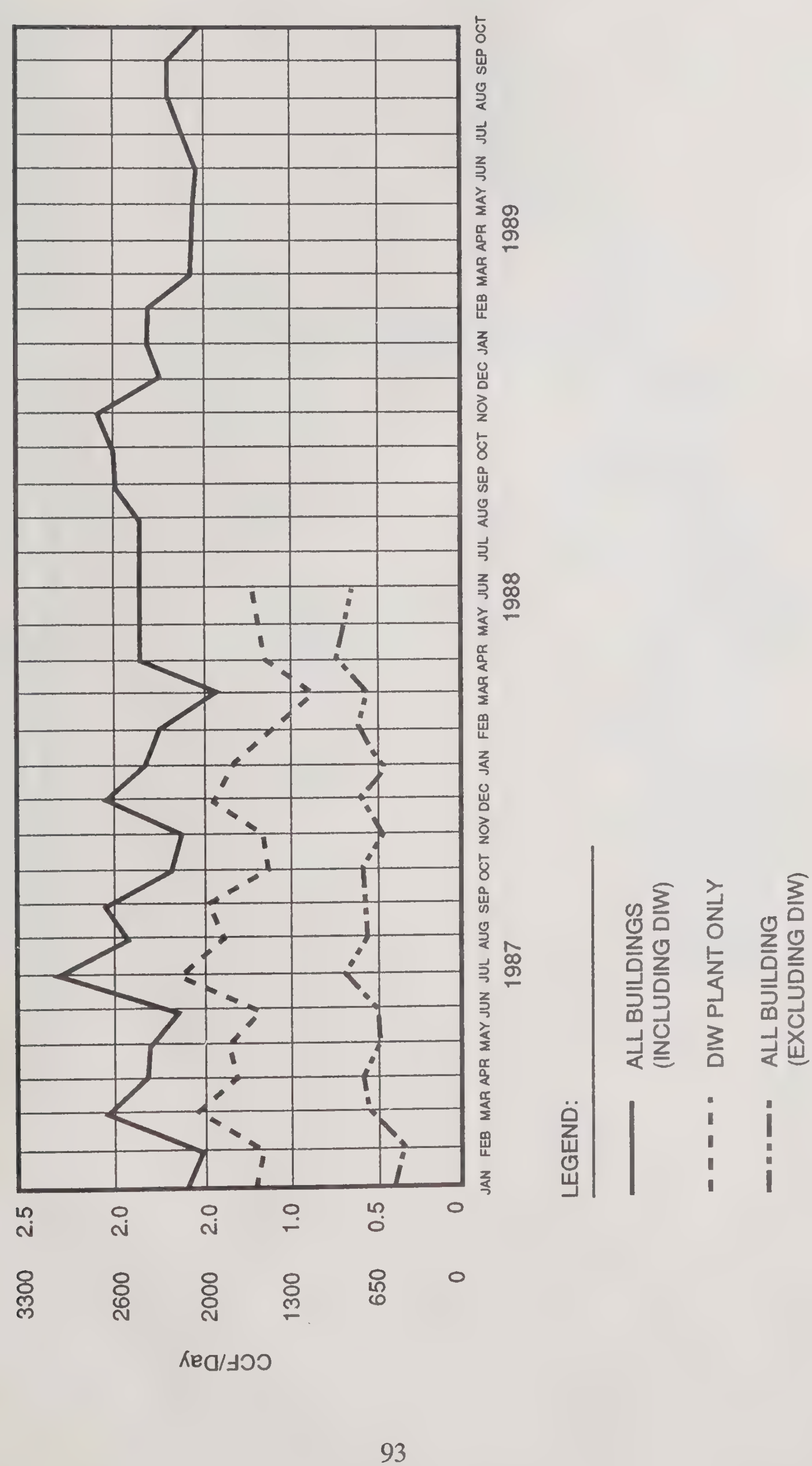


Figure 1 Component of Water Use at National Semi Conductor Santa Clara Facilities 1987.

Figure 2. City Water Consumption at National Semiconductor



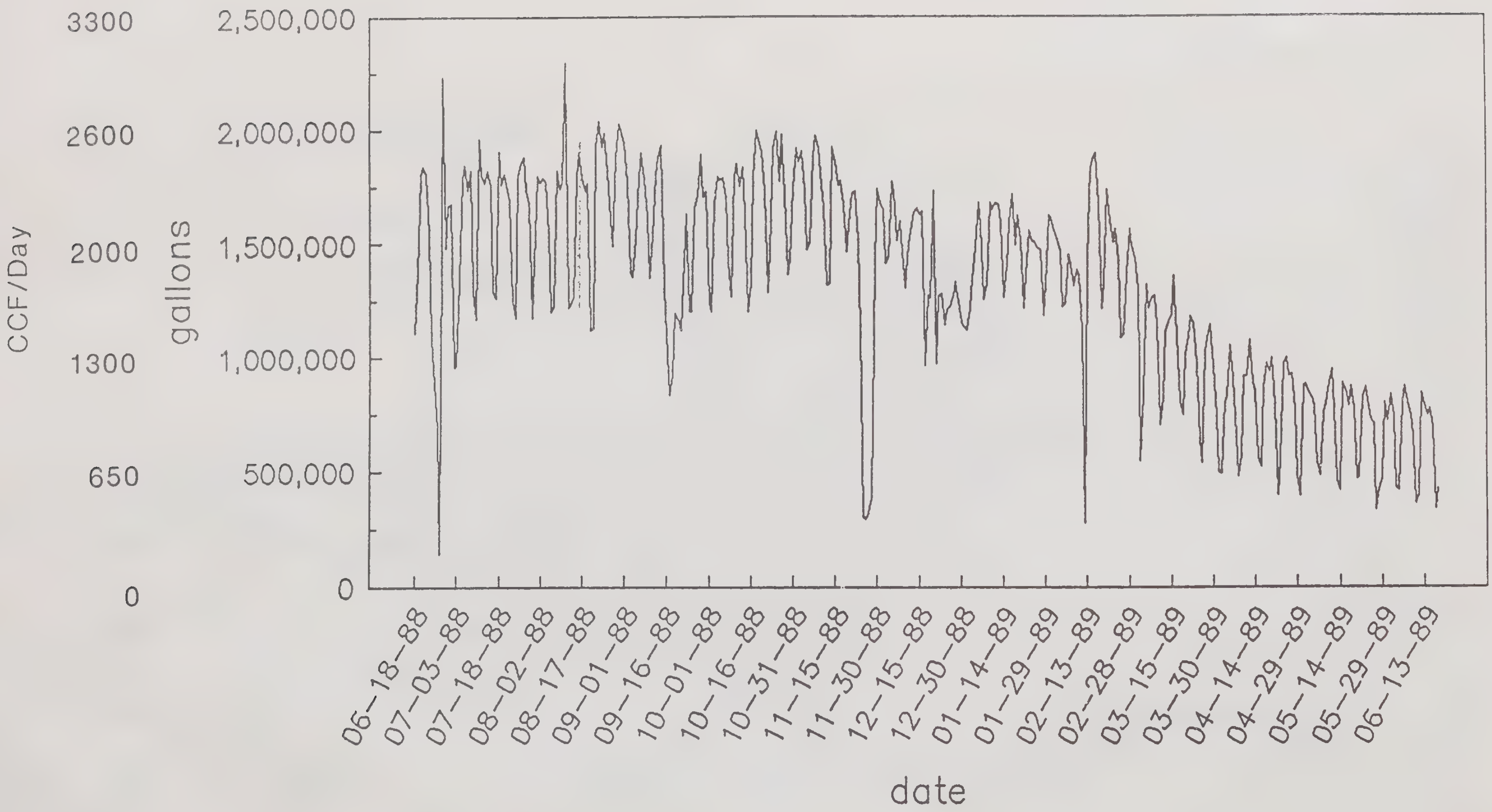


Figure 3 Daily Wastewater Volume, NSC System

B.8

WATER CONSERVATION AT SPECTRA DIODE LABORATORIES, INC.

Brown and Caldwell
January 18, 1990

WATER CONSERVATION AT SPECTRA DIODE LABORATORIES, INC.

Description of Facility and Business

Spectra Diode Laboratories, Inc. (SDL) manufactures laser diodes in a San Jose facility built very recently--in December 1987. SDL opted to incorporate a broad range of water conservation features into the facility's original design. Thus, this case study provides an interesting look at a facility which has practiced water conservation since startup.

SDL operates 24 hours per day. The major water uses at the facility are:

1. Equipment cooling.
2. Deionized water (DIW) rinsing.
3. Fume scrubbing.

Each of these uses is water efficient.

Description of Conservation Actions

SDL installed flow meters on major equipment, with computerized control of water use. Also, a formalized daily inspection monitors against leaks and wasteful operation.

Furthermore, landscape irrigation is conducted on a controlled, nighttime schedule.

In addition to these actions, SDL's major water uses-equipment cooling, DIW rinsing, and fume scrubbing--incorporate water conservation features, as described below.

> Cooling Water. SDL uses water recirculating water to cool heat-generating equipment. For example, the vacuum pumps require 5 gallons per minute (gpm) of cooling water to maintain an appropriate operating temperature. The total recirculating cooling water flow rate at SDL is 90 gpm.
>
> In performing its function, the cooling water picks up heat, rendering it less efficient for subsequent cooling. In decreasing order of water usage, the options for supplying a steady flow of efficient (low temperature) cooling water are: (1) continuously using fresh water ("once-through cooling"), (2) employing evaporative cooling towers, and (3) air chilling the water.
>
> SDL uses air chilling, which operates on the same principle as a radiator in a car; that is, a fan blows air past finned tubes carrying the recirculating cooling water, so that heat is conducted away from the high surface area of the fins. SDL's two air heat exchangers have a total of 150 tons of refrigeration power, where 1 refrigeration ton equals 12,000 Btu per hour. This system involves essentially no water loss. To implement such a water conserving measure, SDL accepts a higher

initial capital cost and energy use than the other two options mentioned above. Capital cost for two 75-ton air chillers is about $20,000, about twice the capital cost for cooling towers of comparable capacity. Fans for the air chillers require 40 horsepower (HP), incurring energy costs of about $30,000 per year; by comparison, annual operating and maintenance costs for comparable cooling towers would be about $5,000 to $10,000.

Deionized Water Rinsing. DIW is used to rinse various electronic parts after processing by contact with acids and other chemicals. Total DIW use is 40 gpm. Some DIW rinses occur in baths (immersion rinses) and others are accomplished by hand under a faucet (manual rinses). Both types feature water conservation.

The conservation feature of the immersion rinse system is that it does not use "plenum" flushes--DIW flushed from a header rimming the rinse tank to clean the tank between rinses. SDL determined that plenum flushes are not necessary and avoided this potentially wasteful practice.

To reduce DIW use during manual rinses, DIW rinse sinks have faucets with spring-loaded valves. Thus, DIW discharges only when the operator holds the valve open.

Fume Scrubbing. SDL generates acidic fumes which are scrubbed prior to discharge to the atmosphere. The scrubbing system involves two towers in which recirculating water, dosed with (alkaline) sodium hydroxide, neutralizes the acid. The water can be recirculated because of the alkaline addition; otherwise, the water would become acidic and thus ineffective for scrubbing subsequent acid fumes. The recirculating water flow in each scrubbing tower is 80 gpm, 24 hours per day. Only about every 3 months is the water changed. SDL accepts the chemical use requirements of this system to conserve water.

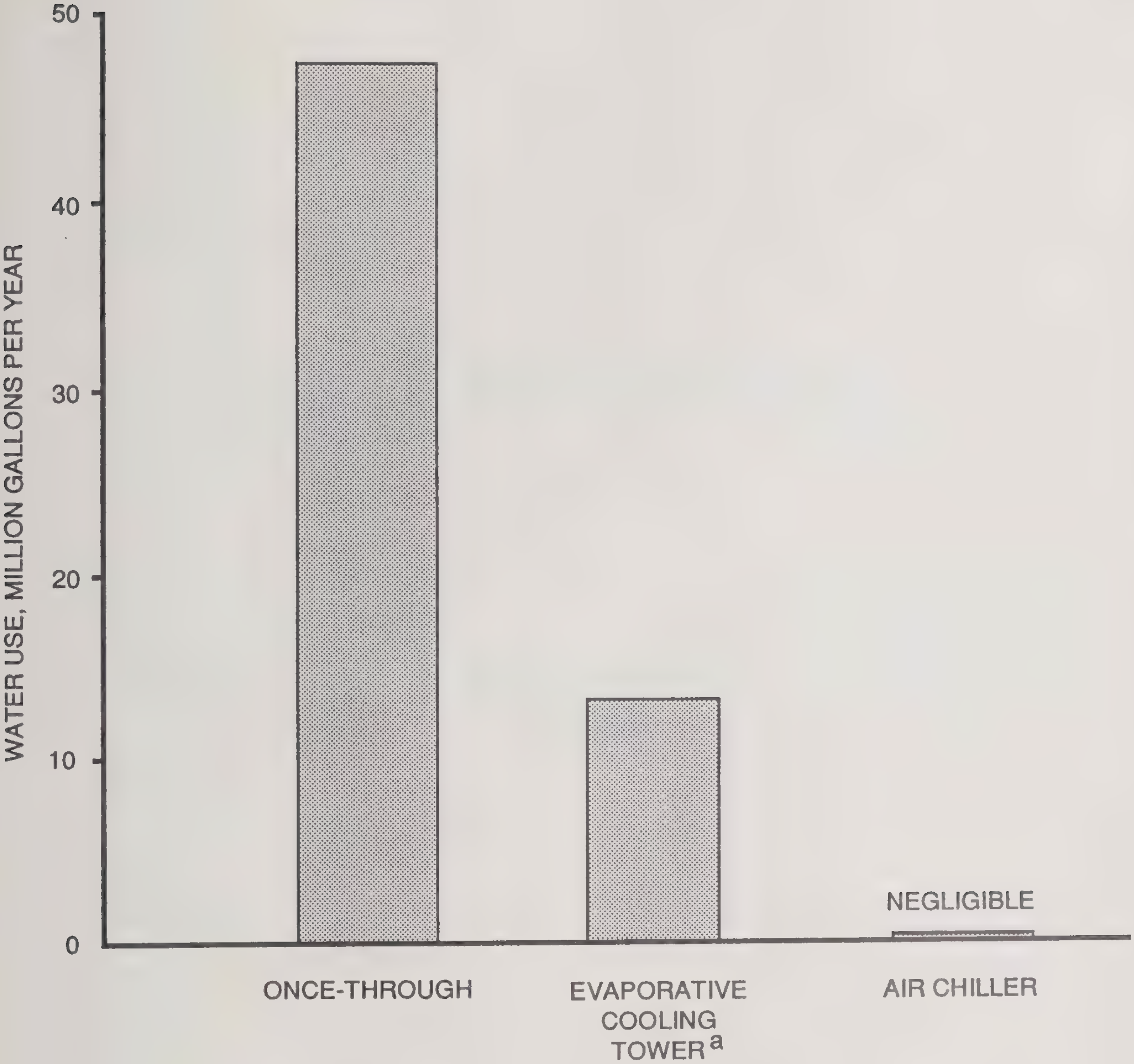
Benefits

Because this new facility was designed with the water conservation features just described, there are no before-and-after results from any recent changes. However, benefits can be demonstrated by estimating the water use that would be required if SDL had adopted alternatives to the conservation features. The two hypothetical examples discussed below concern the use of a cooling tower rather than an air heat exchanger for the cooling water and a lower recirculation rate for fume scrubbing.

Evaporative cooling towers are often used to maintain the temperature of cooling water. (In fact, towers are a water conservation technique compared with wasteful once-through cooling.) Still, a tower typically must blow down about 15 to 25 percent of the recirculating water flow rate to control the buildup of dissolved solids. In addition, losses to evaporation and drift may amount to 10 percent of the recirculating rate. Therefore, a 90-gpm evaporative cooling tower would require makeup water at a rate of about 25 gpm, or 36,000 gallons per day. SDL conserves this quantity of water by using the air

heat exchangers. Figure 1 compares a hypothetical case of annual water usage for once-through cooling, evaporative cooling towers, and air chilling, with all systems at 90 gpm.

In acidic fume scrubbing systems, the scrubbing water is often used just once or else partially recirculated. Since SDL's scrubbing system involves 160 gpm (80 gpm per tower), the potential additional use ranges up to 230,000 gallons per day.



[a] Assumes makeup equals 25 gpm.

Figure 1 Water Use Rates for Different Cooling Water Systems

B.9

WATER CONSERVATION AT TANDEM COMPUTERS INCORPORATED

Brown and Caldwell
December 28, 1989

WATER CONSERVATION AT TANDEM COMPUTERS INCORPORATED

Description of Facility and Business

Tandem Computers Incorporated is a Fortune 500 company which markets computer systems and networks for on-line transaction processing. These systems are used extensively at banks, telephone companies, stock exchanges, and many firms which require instantaneous processing and recording of business transactions. Tandem is headquartered in Cupertino, California, and occupies a total of 23 buildings, most of which is office space and small research labs in the south bay area.

City water sources supply all of Tandem's water requirements. Major water uses include landscape irrigation, laboratory process water, cooling water for air conditioners, a swimming pool, sanitary water, and drinking water. Wastewater is discharged to the city sewer system.

The motivation behind Tandem's pursuit of water conservation was to reduce costs and to demonstrate its concern for the surrounding community. Tandem believes that being a good neighbor is a "win-win" situation for everyone involved. Tandem also has a major energy conservation program, but this report focuses on water conservation.

Description of Conservation Actions

The major water conservation actions at Tandem were minimization of water consumption for landscape irrigation and reuse of water when possible in the laboratories. Since 60 to 70 percent of Tandem's water use is for irrigation, water conservation in this area greatly affects overall consumption. Tandem has worked closely with a landscaping contractor to install a computerized watering system on site. This engineered electronic system allows Tandem to program watering periods according to plant and soil type and also provides readouts of water consumption. A portable hand-held infrared scope is used to monitor the moisture content of plants in order to determine stress levels. Plants receiving near minimum irrigation should have relatively low moisture content and show minor stress.

The installation of this system required the following preliminary steps:

1. Take baseline readings of existing plants and soil.
2. Inventory plants and water delivery system.
3. Upgrade timers, which can be controlled by a new remote system, for control of watering cycle and duration. The timers schedule more frequent, but shorter watering patterns to maximize percolation and minimize runoff.
4. Install rain monitors to prevent irrigation during rainy periods.
5. Change spray heads to optimize flow according to plant types, soil absorption, and landscape layout.

6. Change to drought-tolerant grass types.
7. Prepare proper soil for new plantings and installations, including application of redwood compost mulch.
8. Use infrared scope to monitor index stress levels of plants.

Another major conservation measure was to recycle fume scrubber water. In July 1988, an 8-gallon-per-minute (gpm) once-through scrubbing flow was converted to a closed loop recirculating system. Furthermore, makeup water for the scrubbing system is reverse osmosis (R.O.) reject water, rather than fresh water. The R.O. reject water would otherwise be discarded to the sewer. Therefore, the reuse provides water savings equal to the entire flow.

R.O. reject water was also tried for makeup to two cooling towers. This was discontinued after ozonation treatment was installed for the cooling towers because the effect of ozonation was to greatly reduce the demand for makeup water.

Other efforts to conserve water include:

1. The installation of an ozone generator to treat cooling tower water. This has reduced the amount of blowdown and eliminated the need for chemical treatment. Disassembly of the chiller after about 90 days of ozone operation showed no significant corrosion or scaling on heat exchanger surfaces. Data are not available on makeup flows prior to ozonation, when chemical water treatment was used.
2. Daily covering of the swimming pool to reduce heat loss and evaporation.
3. Installation of water meters on major uses including the cooling towers and swimming pool.
4. Installation of flow restrictors in showers and toilets.
5. Initiation of an employee awareness program including posters, electronic mail, and videos to promote water and energy conservation (see Attachment A).

Results

The amount of water savings due to individual conservation measures is not available since some uses were not previously metered. However, overall savings can be determined using historical data from seven buildings totaling over 750,000 square feet of space. In Table 1, water consumption data for 1988 and 1989 fiscal years (October through September) are compared to data from the preconservation 1987 fiscal year for each of the seven buildings. Water flows are in hundreds of cubic feet (ccf) per year.

A valuable set of data available for Tandem facilities is water use data for a 140,000 square foot, two-story building at which water conservation measures described above were not implemented. This was done intentionally to provide a control case to isolate the effects of water conservation techniques from other variable factors such as rainfall , humidity, and temperature. This building (Building H in Table 1) has similar water uses, and is in the same location as the other seven buildings.

The total savings for the seven water conserving buildings in the first year of new actions was 7,647 ccf, or about 5.87 million gallons of water. This represents a 17 percent reduction in water use over a one year period. The same water conservation measures plus additional measures were implemented in five new buildings of over 400,000 square feet. An additional 2.5 million gallons were estimated to have been saved by implementing conservation measures in these buildings which came on-line during the 1988 fiscal year.

This water conservation has been achieved during a period of continual business growth. Therefore, reductions in water use cannot be related to reduced activity at the Tandem campus.

Using the control case (Building H) to normalize the data, the impact of water conservation was greater than directly apparent. Assuming that the factors which increased the water demand at Building H were also occurring at the seven buildings where conservation measures were being made, then the effect of the measures was to provide a 32 percent decrease in water demand.

Water savings were generally sustained over the two year period. In fact, on the basis of actual water consumption, slightly higher (18 percent) savings were achieved in the second year than in the first year. Even when normalized, the lower water use was not only sustained, but additional savings were made in the second year. Only one of the buildings--Building D--showed a return towards earlier water use levels.

Another way to analyze the water savings is on a monthly basis. Figure 1 presents a comparison of the combined monthly water use during fiscal years 1987, 1988, and 1989, for the seven buildings at which conservation measures were implemented. The water consumption totals were lower during fiscal year 1988 in all but the first month. This graph also shows a trend towards increased water savings, which demonstrates the long-term effectiveness of this conservation program.

Normalization for year to year variations was also done for the monthly total water use at the seven buildings at which water conservation was implemented. The normalized data (relative to the trends of Building H) are presented on Figure 2. With this consideration of the control case, the benefit of water conservation actions is shown to be even greater than actual water flow data indicate.

Costs and Benefits

The saving of 7,647 ccf of water in the seven buildings reflect a cost savings of $9,000 from the previous year. Capital and operational costs for water conservation measures were approximately $28,000 for the first year. An additional benefit due to the changes made is a reduction of operation and maintenance labor due to automation. This benefit has not been quantified, but is roughly valued at $10,000 per year.

A conservative estimate of the cost effectiveness of the measures implemented at Tandem Computers can be made by assuming that the water savings achieved in the first 2 years will be sustained, with no further conservation. Combined reduced water use of 14,194 ccf per year, at a current value of $1.25 per ccf, provides a benefit of $18,000 per year. Adding O&M savings of $10,000 annually, and comparing to the initial investment shows a cost recovery period of one year. Additional cost savings can be expected to occur due to lower sewer fees ($0.60/ccf), since sewer fees are based on metered water intake. Assuming that all reduced wastewater discharge is associated with the 8-gpm savings from scrubbing fumes with R.O. reject, annual cost savings are about $3,000.

Discussion

Water conservation at Tandem's Cupertino facilities was very successful. A 17 percent reduction in water use for seven of its buildings was achieved in the first year. This was repeated the second year with a reduction of 18 percent. Conservation resulted in a 35 percent lower water consumption over 2 years. A control case indicates that the actual effect due to water conservation actions was greater in the first year (32 percent) and totalled more than actual water use indicates (45 percent over 2 years). Additional conservation was noted at five newer buildings, but without baseline data, the impact of conservation measures can only be estimated. Having installed an engineered irrigation system, among other measures, Tandem has reduced its water demand. The conservation measures provided savings sustained over the 2-year period since implementation.

The water conservation techniques successfully used by Tandem are applicable to a wide range of facilities. The engineered irrigation system is unique in that it can be immediately adjusted to meet the monitored demand. However, the key elements of the landscape irrigation water conservation technique are very basic and can be applied to several other water uses. These elements are:

1. Identify major water uses and provide regular monitoring of these uses.
2. Evaluate the minimum water quantity needed for these uses.
3. Plan alternate equipment or operation to minimize water use.

Reuse is another water conservation technique demonstrated successfully at Tandem. Reusing water must be done within limits of required water quality. Elements of this technique are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Evaluate the degradation of water quality resulting from use in each process.
4. Evaluate whether this water can be reused in another process.

A third category, monitoring operations, has the elements:

1. Establish what are reasonable water use practices, including amounts and frequency of use.
2. Notify employees of these proper practices.
3. Monitor and enforce proper water use practices.

Attachment A

ASSOCIATION NEWS

Chapter Spotlight

Working in "Tandem" Pays Off

The definition of the word "tandem" is people or parts "working in conjunction with each another". Based on the expansive success of its energy management program, Tandem Computers Incorporated is definitely living up to its name. By allowing a dynamic energy manager and advanced energy technologies to work together, Tandem has reduced its energy consumption by 7,083,000 kWh in the past two years, a decrease of 15%.

A Fortune 500 Company, Tandem manufactures and markets computer systems and networks for on-line transaction processing. Tandem's systems are vital to the operation of banks, telephone companies, stock exchanges and other firms where thousands of business transactions must be processed and recorded instantly. With over a billion dollars in sales in 1987, some of Tandem's customers include the New York and American stock exchanges, First National Bank of Chicago and Telecom Australia.

From Tandem's headquarters in Cupertino, California, Facilities Engineer William Elam manages the energy consumption of twenty-three buildings in San Jose, Santa Clara, Cupertino and Sunnyvale. These office buildings, research and development facilities and manufacturing plants cover a total of 1,700,000 square feet of space. Elam, together with Senior HVAC Engineer Tony Franciotti and Senior Electrician Izzet Niazi, monitors and controls the operation of Tandem's buildings via a Tandem PC that is linked to fourteen Control Pak energy management systems.

Explains Elam: "This EMS network is like a crystal ball. It can monitor and turn various types of equipment on and off in the buildings and zeroes in on any problem that might occur. It allows us to take care of problems in outlying facilities by modem so we don't have to leave the central office." The energy management systems monitor and control the status of approximately 150 points per building, regulating parameters such as building temperature, air pressure, chilled water flow, lighting and hours of operation.

Tandem also recently installed a Thermal Energy Storage System in its corporate headquarters that makes ice at night at only $.045 per kWh. This ice bank cools the building during the day, allowing Tandem to shut down its chiller during the peak demand period and save thousands per month. The firm received a one-time rebate of $76,200 from Pacific Gas and Electric for shifting 381 kilowatts of load.

Water conservation is also incorporated into Tandem's energy management program. Elam finds secondary uses for process water whenever possible and works closely with a professional landscaping company that installed a computerized watering system on Tandem's grounds.

This electronic system allows the user to program watering periods for various plants and provides electronic readouts of water consumption per plant type.

Elam also represents Tandem on the San Jose Industrial Water Conservation Advisory Committee. This group consists of representatives from large South Bay Area corporations, the City of San Jose, the San Jose Municipal Utility District, and the Department of Water Resources. The purpose of this committee is to work together to develop and implement commercial water conservation strategies.

"We pursue energy and water conservation because it reduces Tandem's costs. But we also do it because its good for the community around us.", says Elam. He believes that APEM assists Tandem in being a good neighbor by allowing him to visit other sites to get ideas for implementing sound energy management programs.

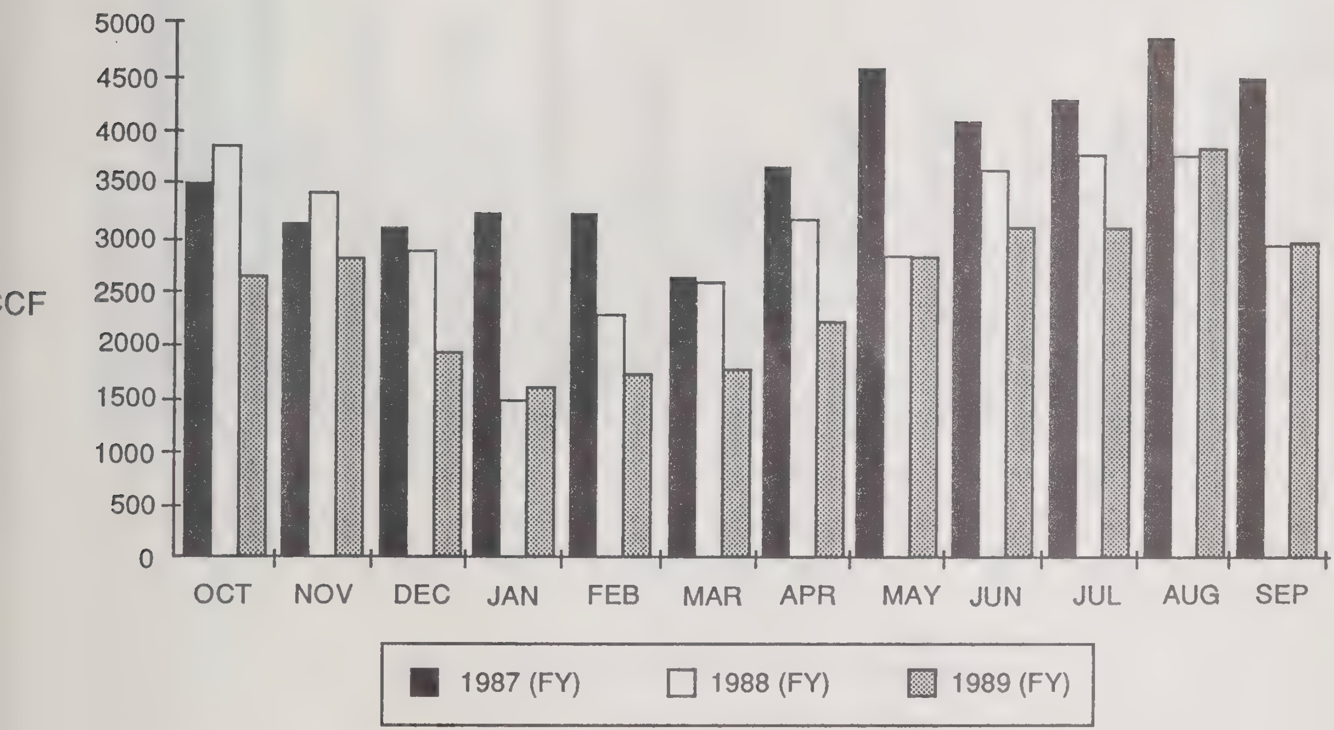
Tandem Pursues Water and Energy Management

Table 1. Annual Water Consumption, (ccf)

Conserving Building	1987 (FY)	1988 (FY)	1989 (FY)	Savings (ccf) 1st Year	2nd Year
A	13,426	11,735	6,150	1,691	5,585
B	10,464	9,151	8,058	1,313	1,093
C	13,459	10,956	9,876	2,503	1,380
D	5,775	3,876	5,267	1,899	<1,391>
E	515	472	465	43	7
F	596	480	398	119	82
G	484	405	314	79	91
TOTAL	44,719	37,075	30,528	7,647 = 17%	6,547 = 18%
BUILDING H (CONTROL)	5,743	6,959	6,557		
Normalized Total[a]	-	30,597	26,738	14,122 = 32%	3,859 = 13%

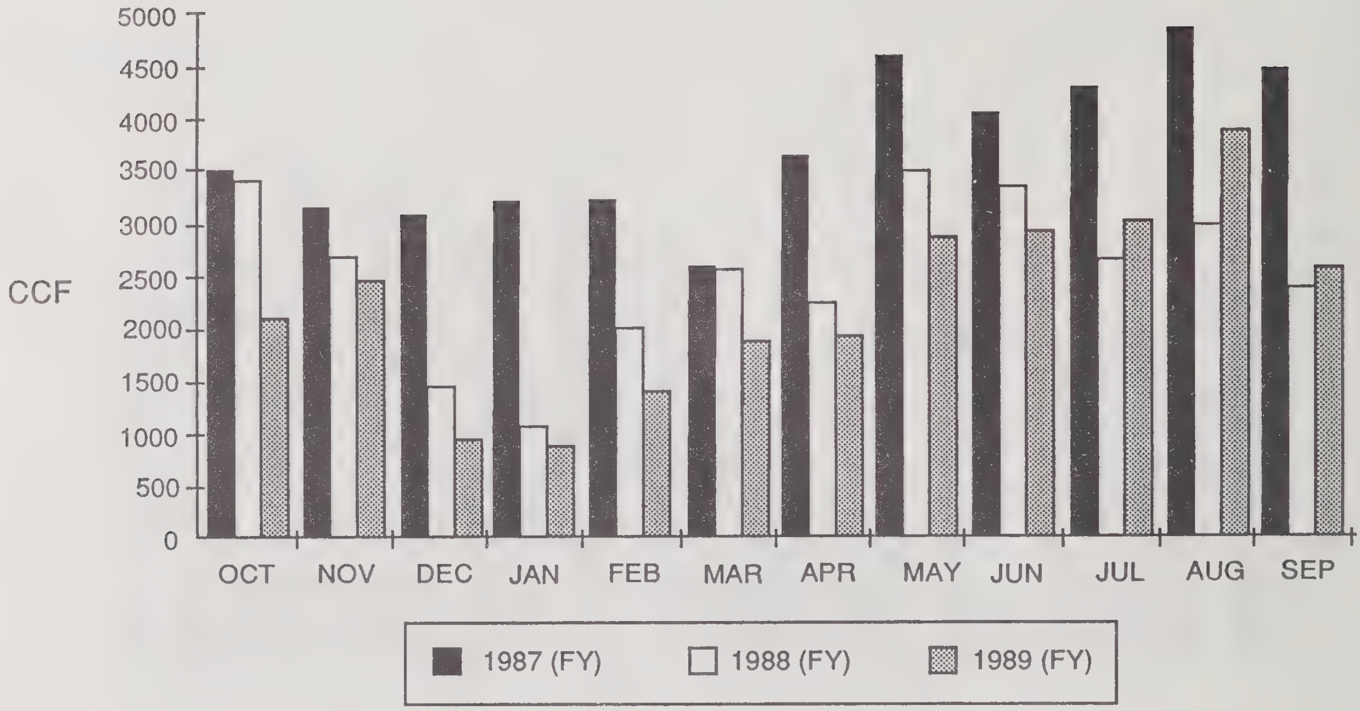
[a] Example calculation of normalized values for 1988 (FY):

1. Normalized total = 5,743/6,959 x 37,075 = 30,597.
2. Normalized savings = 44,719 - 30,597 = 14,122.
3. Normalized percent savings = 14,122/44,719 x 100 = 32 percent.



Monthly volumes assume 30-day months

Figure 1 Monthly Comparison of Water Use,
Tandem Computers Incorporated
1987, 1988, and 1989



Monthly volumes assume 30-day months

Figure 2 Normalized Monthly Comparision of Water Use,
Tandem Computers Incorporated
1987, 1988, and 1989

B.10

WATER CONSERVATION AT XEROX PALO ALTO RESEARCH CENTER

Brown and Caldwell
December 28, 1989

WATER CONSERVATION AT
XEROX PALO ALTO RESEARCH CENTER

Description of Facility and Business

This report addresses innovative water conservation techniques used at Xerox Palo Alto Research Center. This research and development facility comprises two buildings. One has a floor area of 70,000 square feet, the other 210,000 square feet. Approximately 350 people work in these buildings. Operations at this facility include offices and a semiconductor laboratory.

All of the water supply at this facility is from the City of Palo Alto. This water is normally from the Hetch-Hetchy system, having a typical total dissolved solids (TDS) level of 20 mg/L as compared with lower quality groundwater in Santa Clara county that typically has 200 mg/L TDS. Electric power is also obtained from the City of Palo Alto. Major water uses have been makeup for cooling towers for air conditioning and laboratory machinery cooling, process water including ultra pure water production, and landscape irrigation.

Conservation Actions

Water conservation at the Xerox Palo Alto Research Center in the last three years has included the following:

- Eliminating blowdown flow from cooling towers by changing to ozonation for cooling tower water treatment.
- Connecting some cooling loads from once-through water use to a cooling tower loop.
- Implementing of a water use monitoring program and employee education program.
- Modifying operation of the landscape irrigation system.

At Xerox Palo Alto Research Center, the effort for conservation of water was integrated with conservation of other resources. Consideration was also given to cutting peak and total electrical use, lowering wastewater quantities, and minimizing use and disposal of hazardous chemicals. For example, most of the types of hazardous chemicals kept at this site were for chemical treatment of cooling tower water. These additional conservation considerations will be discussed in this report if they pertain to the water conservation technique.

Results

Ozonation. Several benefits have resulted from the conversion from chemical treatment of cooling water to ozonation treatment. First, with a direct impact on water consumption, is the elimination of blowdown flow from cooling towers.

Blowdown was needed with chemical treatment, but has been unnecessary with ozonation. Blowdown is the discharge of part of the circulating water, which has become concentrated with minerals due to evaporation. The blowdown is then replaced with clean water having a lower mineral content. Blowing down water from an evaporative cooling system is necessary to prevent oversaturation of the circulating water. Oversaturation would allow precipitation of minerals out of solution in cooling water. Problems occur if the precipitates form a coating of scale on heat exchanger surfaces, such as pipes in a chiller. Insulating scale cuts down on heat conduction through the surfaces. Severe scaling also causes more friction in the pipes, thus requiring more pumping energy.

At Xerox Palo Alto Research Center, conversion to ozonation from chemical treatment ended scaling. In fact, scale that had been present was observed to slowly come off of the chiller tubes during the first 1 to 2 months of ozonation--a second benefit of ozonation. The removed scale and other solids accumulated as sludge in the cooling tower pan. The pan has been vacuumed to remove sludge 3 times in the first year of ozonation. This is the only removal of water for waste disposal, consisting of a few hundred gallons of water removed with the sludge. Previously, the volume of blowdown for the two cooling towers was about 2 million gallons per year. The third benefit of ozonation is excellent disinfection. Although chemical treatment accomplished disinfection, ozone is a more powerful disinfectant. (Because of this, ozonation has also been added to the circulating water loop on fume scrubbers at Xerox Palo Alto Research Center to control algae.)

The risk of corrosion was the major concern during conversion to ozonation at Xerox Palo Alto Research Center. Because ozone is a powerful oxidant, it poses a risk of corrosion damage to valuable and vital cooling equipment. Piping in the Palo Alto Research Center cooling system is made of mild steel, and the condenser tubes of copper. Inspection of the heat exchange surfaces upon disassembly of a chiller showed no evidence of corrosion, pitting, or slime buildup. Corrosion rates were measured and found to be acceptably low. They are listed in Table 1, below.

Table 1. Corrosion Rates Measured in the Xerox Palo Alto Research Center Cooling System After Installing Ozonation.

Material	Corrosion Rate, mils/year
Mild Steel	<0.9
Copper	0.5
Brass	0.65
Zinc	0.7

(Note: 1 mil = 0.001 inch)

In addition to conserving water, the conversion to ozonation at Xerox Palo Alto Research Center lowered energy demand. One place this was seen was in a big increase in the efficiency of the chillers. On the 120 ton (refrigeration tons) chiller, the volumetric efficiency of the compressor increased from 76 percent to 82 percent.

A key to successful use of ozonation at Xerox Palo Alto Research Center has been monitoring and control of the ozonation system to maintain proper ozone concentrations. In one of the cooling towers, initial ozone dosage was too high, and an ozone odor was detected adjacent to the cooling tower. The dosage was therefore cut by 75 percent. This was too low, however, and the condenser soon plugged. Raising the ozone dosage remedied the plugging. At the other cooling tower, the ozone dosage has been kept in the range of 0.01 to 0.03 parts per million (ppm). Operators also monitor oxidation reduction potential (ORP), a measure of the ozone's power to capture electrons (associated with disinfection and reactions with metals, for example). ORP is maintained above 450 millivolts.

Stop Once-through Cooling. In 1987, a major water conservation action was made. This was the connection of some cooling loads from once-through water use to a cooling tower loop. There are, however, no data available to quantify the water savings achieved.

Monitoring. Implementation of a water use monitoring program and employee education program has also contributed to water use reduction at Xerox Palo Alto Research Center. Monitoring includes twice-daily readings of water meters to provide a database of normal water use and enable detection of major losses. Also, sensors and an alarm were installed on two flow meters in a closed loop deionized water (DIW) system for the laboratory. Occasionally, the water runs unnecessarily because a manual valve is left open or autocycle valves stick open. Differential readings on the two meters indicate water use from the system. During the night when the laboratory is closed, any flow greater than 2 gallons per minute (gpm) will set off an alarm. The night guard can then check for leaks. As these programs are intended to address miscellaneous and marginal use of water, there are no data to evaluate their effectiveness.

Landscape Irrigation Conservation. Modifying operation of the landscape irrigation system included ceasing daytime sprinkling and cutting back on the amount of water used. Irrigation water use at this site was 23 to 24 million gallons per year (70 to 74 acre feet per year) in 1987. Data are not available on the post-conservation flow.

Costs and Benefits

The water conservation action at Xerox Palo Alto Research Center which has been best documented is ozonation of cooling water. The cost-benefit analysis in this report is restricted to this particular technique.

Ozonation. Equipment for ozonation at the two cooling towers at Xerox Palo Alto Research Center was procured from a vendor under a 3-year lease/purchase arrangement. Because of this, the cost of the equipment is annualized. The costs for equipment lease and operating services in 1988 were $14,460 and $17,880 for the two buildings. Xerox's operating costs include electricity and telephone service. The demand for electricity is a 480-volt, 3-phase, 30-amp load per ozonator. Assuming average operation at 65 percent capacity for the two buildings, the total power requirement is 132,000 kW. At a local cost of $0.045/kWh, the annual added energy cost for ozonation is $5,940 per building. In addition to the power charge, a peak demand charge applies. Industries are normally charged a rate based both on power consumed and on their peak electrical demand. The added cost of ozonation for the higher peak demand charge, based on a Palo Alto rate of $6.50 per kWh in the peak, is $1,175 per installation per year. The new cost for telephone lines is for dedicated lines for remote monitoring of water chemistry. This cost at each building was $216 per year in 1988. Total annual new cost of ozonation for both buildings is just under $47,000 per year.

Savings due to lowered water use derive from eliminating blowdown. Previously, blowdown was about 2 million gallons per year. The value of water in Palo Alto is $1.85 per unit (one unit of water is one hundred cubic feet, or 748 gallons), including water supply and sewer fees. Total savings by using ozonation due to lower water usage is approximately $5,000 per year.

Chemical treatment, which was replaced by ozonation, cost $8,512 annually. Additionally, labor costs for chemical treatment were significant. This took about 8 hours per week per cooling tower. The associated savings after stopping chemical treatment is about $20,000 per year.

More Efficient Cooling. The increase in the efficiency of the chillers provided a benefit of lower electrical demand. On the 120 ton (refrigeration tons) chiller, the volumetric efficiency of the compressor increased from 76 percent to 82 percent. The value of this improvement, based on a relatively low cost of electricity of $0.045/kWh, is $5,392 per year. An additional energy savings is accrued, though, because of a lowered peak demand. Conservation that holds continually will cut the peak. The peak demand charge savings due to better efficiency on this chiller was worth $1,092 per year. Total chiller capacity at the Xerox Palo Alto Research Center is 1,434 tons. They are used at only about 70 percent of full load capacity, though, so the extrapolated savings if all chillers had the same improvement in efficiency is calculated to be $53,000 per year.

Cost-Effectiveness of Ozonation. Annualized savings for this conservation technique are listed in Table 2.

Table 2. Cost Benefit Analysis of Ozonating Cooling Water at Xerox Palo Alto Research Center.

Item	Annual Cost or Savings (-), dollars per year
Ozonation Equipment and Operation	47,000
Xerox's installation expenses	1,072
Blowdown water saved	-5,000
Chemicals saved	-8,512
Labor saved	-20,000
Energy saved	-53,000
Total	-38,440 = savings

The major capital investment is being made by the vendor who leases the equipment to the industry. This cost is included in the lease payment and does not occur as a capital cost to Xerox. Therefore, the apparent capital cost recovery period is low. This is meaningful, because Xerox did not take on the burden of the majority of the investment required for ozonation. Capital costs to Xerox for installation were about $8,000. Amortized over 20 years at 12% interest, the annualized cost is $1,072. Comparing Xerox's investment with the savings (not including the amortized capital cost) yields the payback period. The simple capital payback period is $8,000 divided by $38,440, which equals 0.2 years (2.5 months).

Discussion

Ozonation of cooling tower water was seen to provide several benefits in this case study. Blowdown water flow was virtually eliminated. Hazardous chemicals used for the previous treatment were avoided. Mineral scaling in the heat exchangers was reduced, with consequent improvement in energy efficiency. Corrosion, an issue of great concern when implementing ozonation, was shown to be no problem. Cooling towers are a very common. They are present at a wide range of commercial and industrial facilities. The transferability of this water conservation technique is very high.

The cost effectiveness of ozonation was well documented at Xerox Palo Alto Research Center. This cost-effectiveness occurred due to benefits other than lowered water usage. Most important of these factors are energy conservation and reduced labor. Other industrial facilities considering conversion of cooling tower water treatment from chemical methods to ozonation should be sure to analyze the potential cost savings in these areas in addition to the water savings.

APPENDIX C

CASE STUDY COMPANIES--METAL FINISHING INDUSTRY

C.1 - Dyna-Craft, Inc.
C.2 - Hi Density Disc Manufacturing, Inc.

C.1

WATER CONSERVATION AT DYNA-CRAFT, INC.

Brown and Caldwell
January 11, 1990

WATER CONSERVATION AT DYNA-CRAFT, INC.

Description of Facility and Business

Dyna-Craft, Inc. operates a metal finishing facility in Santa Clara, near the border with Sunnyvale, sharing a site with a large National Semiconductor facility (described in a separate report). The source of water is an on-site well owned by the City of Santa Clara. Normal operation at Dyna-Craft is 24 hours per day.

During the study period, 90 percent of the water use at this facility was as rinsewater in a reel-to-reel copper plating operation. In reel-to-reel plating, a continuous metal tape unwinds from one reel, passes through channels containing various chemicals, and winds up on a take up reel (see Figure 1). The processing chemicals and rinse waters overflow the channels and fall into sumps. The processing overflow may be recycled; rinse overflow is discharge to the sanitary sewers. Dyna-Craft has 6 plating machines, processing 3 tapes each.

The steps in the reel-to-reel plating operation are as follows:

1. Alkaline degreasing of tape to be plated.
2. Acid cleaning.
3. Copper striking, using a copper-cyanide solution.
4. Silver striking, using a silver-cyanide solution.
5. Silver plating, using a silver-cyanide solution.

After each step, the metal being plated is rinsed with deionized water (DIW) (except in alkaline degreasing, which is rinsed with City water). Thus, there are 4 DIW rinses per machine, or a total 24 DIW rinses. The rinsewater becomes contaminated with "dragout," the volume of chemical solution that is carried over from the process channel. High dragout volumes require high rinse water volumes.

The motivation for pursuing water conservation was to reduce the wastewater costs associated with discharging rinsewater with metals. Furthermore, water conservation efforts were linked with silver recovery. Finally, there was insufficient storage capacity at the facility to handle the previous rinsewater volumes to be discharged, forcing Dyna-Craft to discharge high peak flows frequently.

Description of Conservation Actions

Dyna-Craft implemented a successful rinsewater reduction program by changing the rinsing machinery. An important component of this program was installing "Air Knives" prior to each rinse. An Air Knife blows dragout back into a process chemical overflow sump before the processed tape enters the rinse tank (see Figure 2). As a result, less water is needed for rinsing.

In addition, Dyna-Craft installed flow restrictors in the DIW rinse. (An electrolytic silver recovery system is also used to further recovery efforts.)

Results

Since installation in April 1988, the Air Knives and flow restrictors have reduced the DIW flow from 4 gpm to 3 gpm per DIW rinse, or a total of 24 gpm. The estimated rinsewater savings is therefore about 35,000 gallons per day, or 12.6 million gallons per year.

Costs and Benefits

Costs associated with the rinsing changes at Dyna-Craft include capital and operating expenses. A compressor supplying clean, dry (oil-free) air is needed for the Air Knives. The cost for such a compressor at Dyna-Craft, including purchase cost and installation, would be about $20,000. (Dyna-Craft already had its compressor, but the capital cost is included in this analysis to address the situation in which all equipment must be purchased.) Capital costs for 100 Air Knives ($20 each) and flow restrictors ($2.75 each) was estimated at $2,300. Thus, the total capital cost is about $22,300. Amortized over a design life of 20 years at 12 percent interest, the equivalent annual cost is about $3,000.

Operating expenses include labor for cleaning the Air Knives and flow restrictors. Proper maintenance is important to protect the Air Knives. Estimated labor costs at 8 hours per week are $8,000 per year. Power costs for the Air Knives are estimated at $2,000 per year. Thus, the combined capital and operating costs for reducing rinsewater flow rate is about $13,000 per year.

Benefits result from reduced water purchase, wastewater disposal, and DIW production charges, estimated at $1.04, $1.26, and $10 per thousand gallons, respectively. With rinsewater consumption reduced by 35,000 gallons per day, 90 percent of which is DIW, avoided costs are calculated as follows:

$/yr = - ($/yr savings from reduced DIW production costs)
- ($/yr savings from reduced water sewer fees)
+($/yr cost to implement conservation system)

= - ($10 x 0.9 x 12,600 = -$113,400)
- ($2.30 x 12,600 = -$29,000)
+($13,000)

= - $129,400, savings

Therefore, the payback period is only 2 months.

Discussion

Water conservation at Dyna-Craft in Santa Clara was very successful. A 25-percent reduction in disposed rinsewater was achieved by modifying the rinsing system, in this case, installing Air Knives which blow dragout into sumps before it can contaminate rinse water. This technique is transferrable to other metal plating facilities.

Key elements of process modification to conserve water are:

1. Identify major water uses.
2. Evaluate and retrofit to use the minimum quantity of water needed for this application.

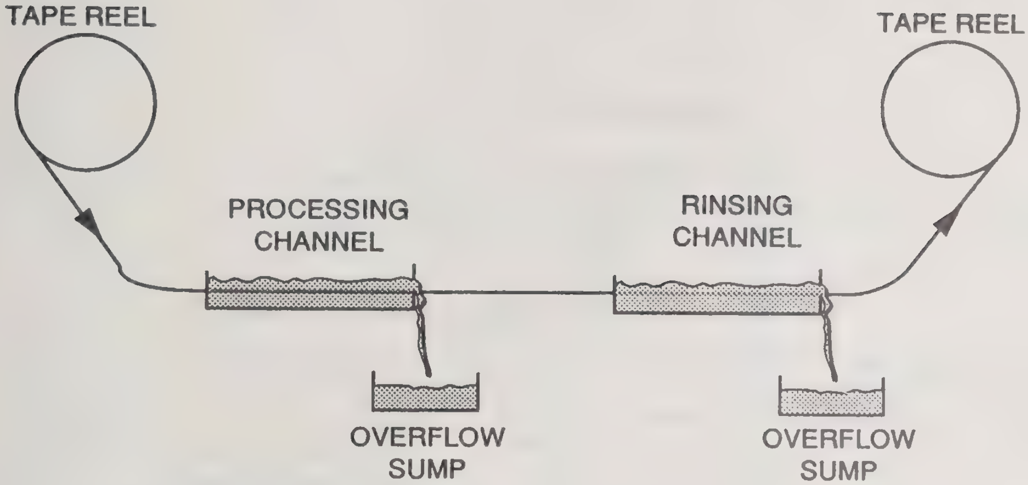


Figure 1 Simplified Diagram of Reel-to-Reel Plating Operation

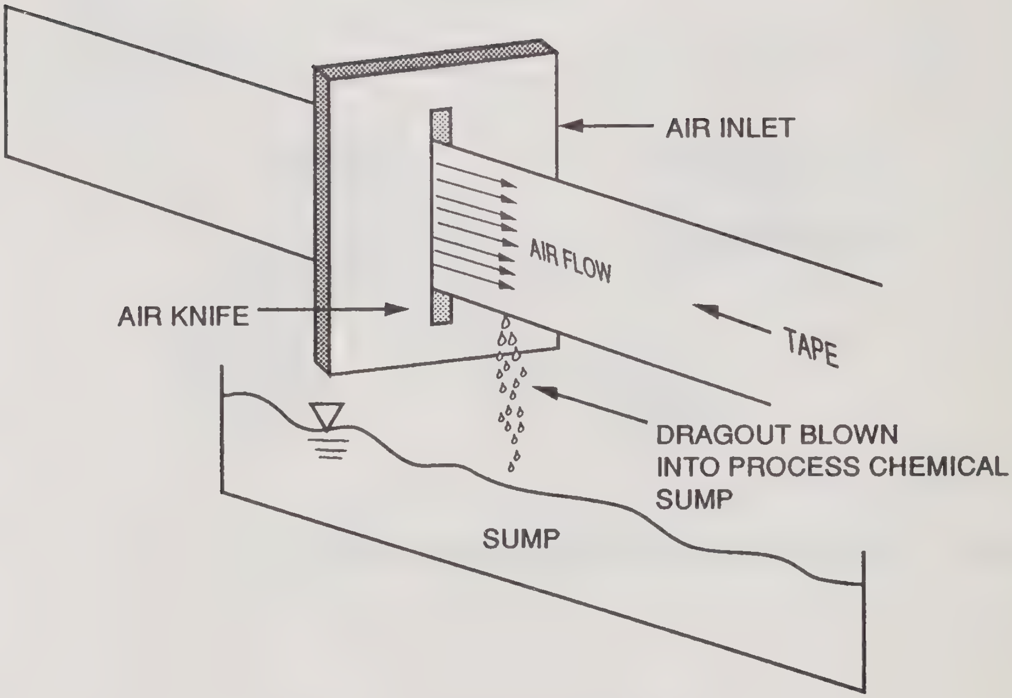


Figure 2 Air Knife Operation

C.2

WATER CONSERVATION AT HI DENSITY DISC MANUFACTURING, INC.

Brown and Caldwell
December 19, 1989

WATER CONSERVATION AT HI DENSITY DISC MANUFACTURING, INC.

Description of Facility and Business

Hi Density Disc Manufacturing is located in an industrial park in North San Jose, an area of particular concern for water conservation because of restrictions on Hetch-Hetchy source water.

Hi Density Disc's business is the manufacture of large magnetic memory aluminum discs for mainframe computers. At this facility, the aluminum alloy discs are baked, ground, and polished. Between these steps, they are spray-rinsed with deionized water (DIW). Rinsing between baking and grinding is termed the first rinse. Rinsing after grinding and before polishing is the final rinse.

A process flow diagram of water usage at the Hi Density Disc facility is shown on Figure 1. Most water usage occurs in disc rinsing, with one loop estimated to have a flow of about 16 gallons per minute (gpm) in the first rinse, and two loops of about 16 gpm each in the final rinse. Other water usage is for restrooms, and floor and equipment hosedown. These flows are only occasional, and add up to much less than the disc rinses. Wastewater is discharged to the City sewer.

The normal operating schedule at this facility is 80 hours per week (4 days per week, 2 shifts per day). There are 10 to 20 employees on each shift.

Past water quality problems, including some leading to plant shutdown, instigated Hi Density Disc's examination of their water system. This examination led to changes, including a conservation program. One water quality concern for Hi Density Disc is the change from low TDS (total dissolved solids) water from the Hetch-Hetchy supply to higher-TDS local groundwater supply. Other past water quality problems were associated with construction in the vicinity of the Hi Density Disc facility, possibly due to suspension of sediments caused by flushing of water supply mains.

Description of Conservation Actions

The major water conservation action at Hi Density Disc has been recycling of DIW rinsewater. Two process changes have been implemented: one in February/March of 1987 recycling DIW in the final disc rinse, and another in March 1988 recycling water in the first disc rinse.

The change to recycling final rinse water involved new equipment for collection of the rinsewater and pumping through a cartridge filter, followed by reuse in the final rinses. There are two final rinse streams, each reportedly about 16 gpm. Previously, DIW rinsewater was used once then discarded. The rinse serves to remove fine metal particles, which can be readily settled or filtered. No significant addition of soluble

materials occurs during the rinse, so it is not necessary to pass the recycled water through the demineralizer columns again. An automatic control system monitors water quality in the recycle water collection tank, and controls blowdown and makeup to maintain pre-set water quality parameters.

One year after implementing recycling of final rinsewater, Hi Density Disc began recycling DIW at another process: the first rinse station. Here, a tap water stream with an estimated flow of 16 gpm was being used once-through for rinsing of discs. Hetch-Hetchy water is preferred for this application. The water conservation change consisted of collection, filtration, and reuse of the water in the same first-rinse process.

In addition to these process changes, Hi Density Disc has applied a strong employee training and monitoring program. Employees have been instructed on the importance of not wasting water. Signs are posted widely to remind workers to save water, and instructions for machinery operation include directions for saving water.

<u>Results</u>

Recycling of final rinse DIW ended consumption of a large flow of DIW previously used once then discarded. Current consumption of water in this process consists of automatically controlled makeup DIW. Figures 2 and 3 show water consumption at Hi Density Disc in, respectively, hundreds of cubic feet (ccf) per month and gallons per month. Figure 4 shows water use in ccf per month with data averaged over 3-month periods (current month, one before, and one after) in order to smooth out fluctuations to show long-term trends.

Recycling of final rinse DIW began in February/March of 1987. Comparison of the average consumption for 14 months preceding this change with the 12 months following the change shows a decrease in water usage of 260 ccf/month (see Figure 4). This equates to a reduction of 9.5 gpm, based upon normal operating hours of 80 hours per week.

Recycling of first rinse water ended consumption of water that had previously been used once then discarded. The circulating flow is estimated to be 16 gpm. Current consumption of water in this process consists of periodic (daily) discharge and refill of this rinsewater tank. This change provides a reduction in water consumption equal to the previous circulating flow minus the daily refill. This refill volume (approximately 200 gal) is minor compared to the circulating flow summed over a 16-hour day (approximately 15,000 gallons). With normal operating hours of 80 hours per week and 4.3 weeks per month, savings are about 440 ccf/month. Recycling of first rinse DIW began in March of 1988.

Figures 2, 3, and 4 show water consumption at Hi Density Disc for the period preceding recycling of first rinse water, but for only a short period following this. Comparison of the average consumption preceding this change with the months following the change shows a sharp decrease in water usage.

Nonprocess water conservation at Hi Density Disc (i.e., floor washdown, restrooms) has been implemented. This has been a positive contribution in reducing water usage, and has supported awareness of water usage. There are, however, no measurements of nonprocess water use, so the benefit of this area of water conservation can not be quantified.

Costs

Costs associated with the process water changes at Hi Density Disc are for capital and operating expenses. However, the changes addressed both water quality needs, and water quantity conservation. Therefore, direct costs for water conservation measures are not separable from water quality control measures. Nevertheless, an indication of the economy of water volume reduction actions at Hi Density Disc can be gathered from knowledge of water supply and sewer fees, and estimates of operating costs for DIW treatment and filtration.

Capital costs for project implementation are estimated at about $5,000 for developing and installing DIW collection, monitoring, and pumping equipment.

Operating costs are for water supply, wastewater disposal, and water treatment. Combined costs of water and sewer service are essentially variable in proportion to water volume--about $2.06 per ccf. Water treatment costs were variously increased and decreased by the modification for DIW recycle. Demand for treatment for initial production of DIW was reduced. Recycling DIW requires additional treatment by filtration--which is less expensive than initial DIW production. Figures on water treatment costs are available for Hi Density Disc for the first three months of 1988. These indicate that the costs of water treatment are variable ($0.03/gallon of DIW) plus fixed ($520/mo. for DIW equipment, and $1075/mo. for filters, electricity for pumping, and added maintenance for the recycling system).

Assigning all of the water usage reduction between 1986 and 1987 to implementation of recycling final rinse DIW, the savings calculated from the above costs and the measured water conservation (-260 ccf/mo.) is:

$/mo.	=	- ($/mo. lower water and sewer fees)
		- ($/mo. lower variable DIW treatment cost)
		+($/mo. added fixed recycling system costs)
	=	- $535/mo. - $5835/mo. + $1075/mo.
	=	- $5300/mo.

The conclusion, based on these cost figures, is that the water conservation was cost-effective, mainly because of the decrease in DI water treatment costs.

Discussion

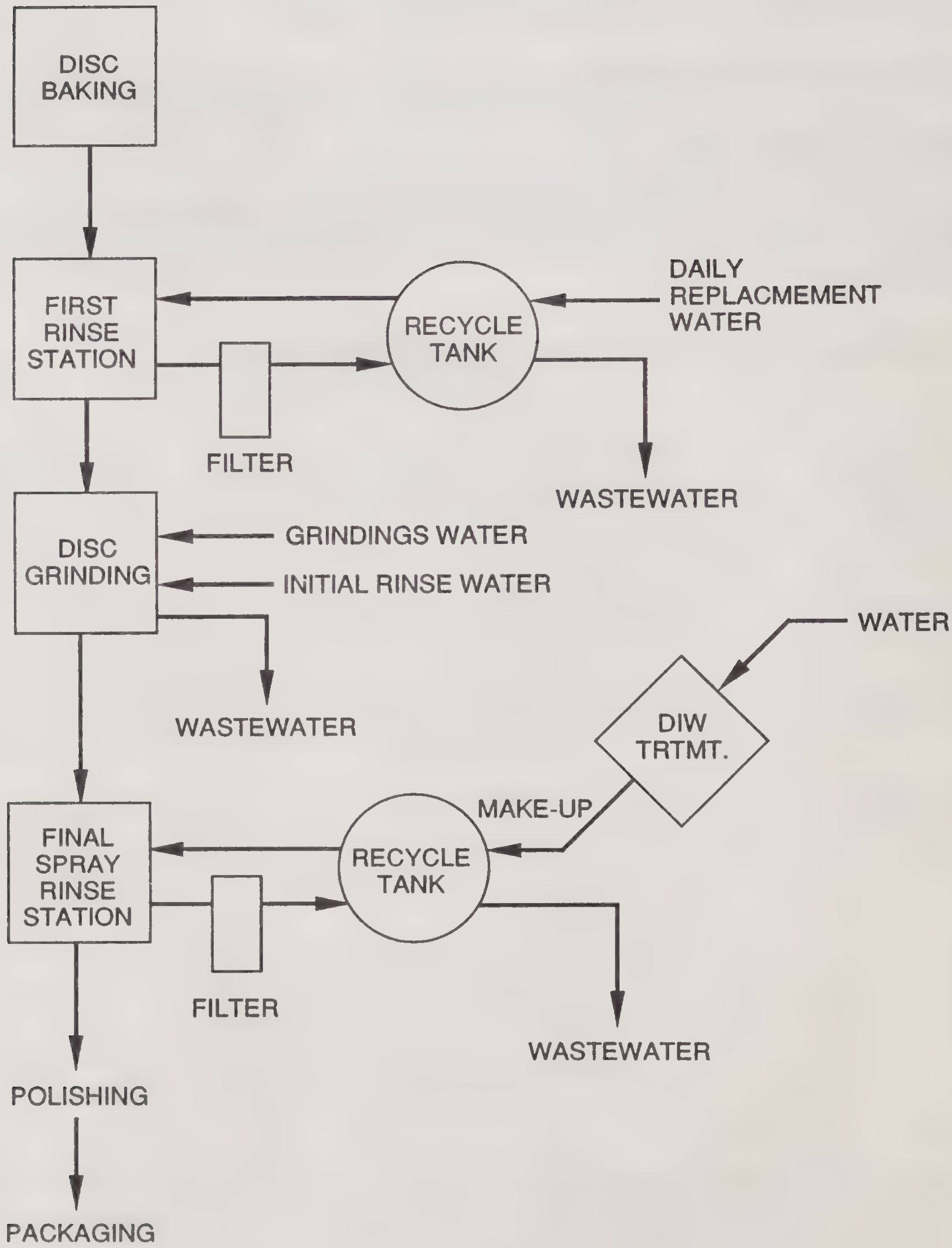
The water conservation techniques successfully used by Hi Density Disc are applicable to a wide range of industries. The key principle applied at Hi Density Disc is that of using the minimum required quality of water. For their rinsing processes, the water needed to be DIW, but was degraded by each use only by addition of particles. Filtration was sufficient to recover the DIW for recycling in the same process.

Elements of this in-process recycling water conservation technique are:

1. Identify major water uses.
2. Determine the minimum water quality needed.
3. Evaluate the degradation of water quality resulting from use in this process.
4. Evaluate whether this water can be recycled for use in the same process with little or no treatment.

These elements can be used in any potential recycling of process water.

Figure 1. Process Water Flow Diagram
Hi Density Disc Mfg. Inc.



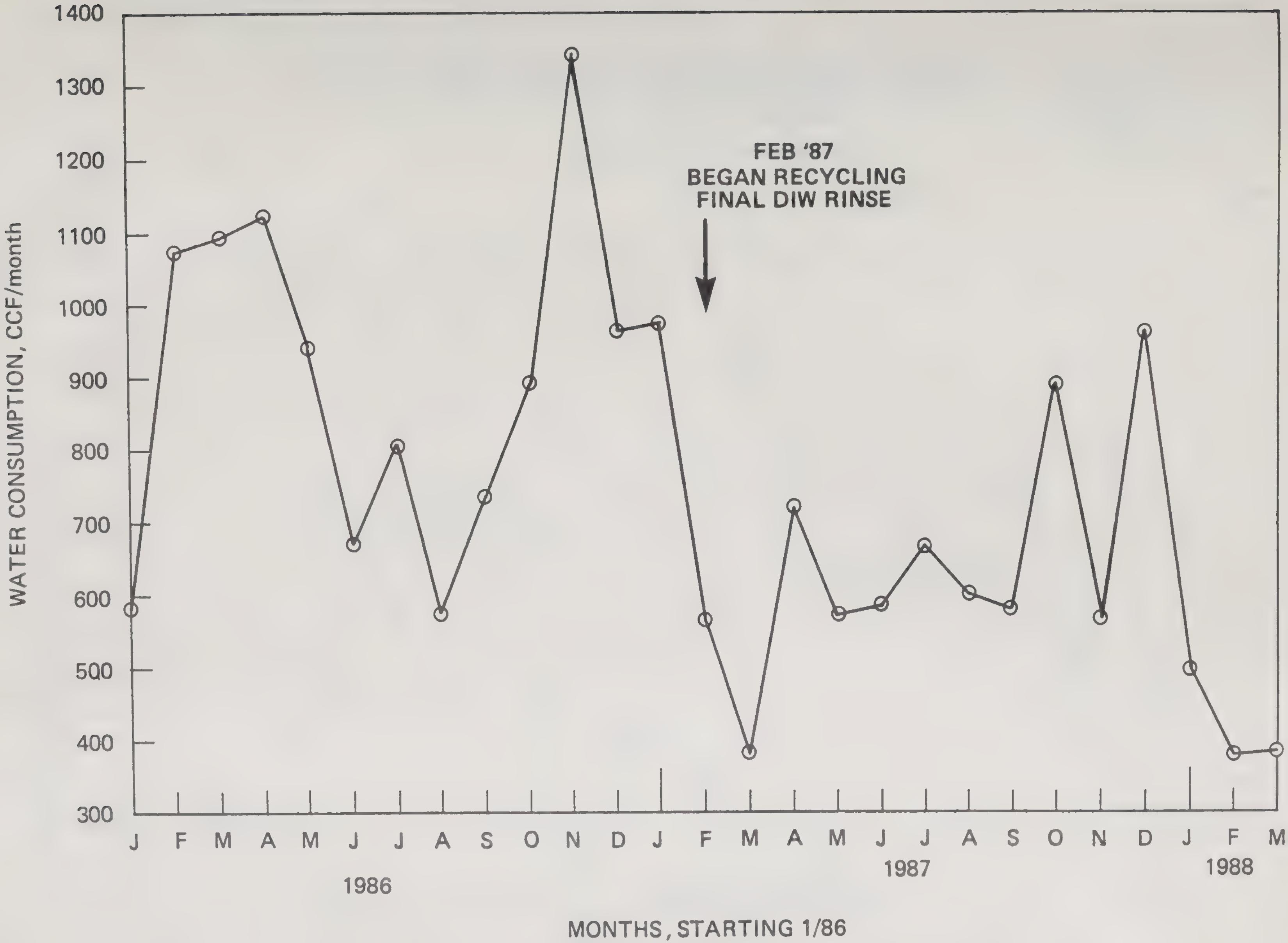


Figure 2 Water Usage at Hi–Density Effects of Water Conservation

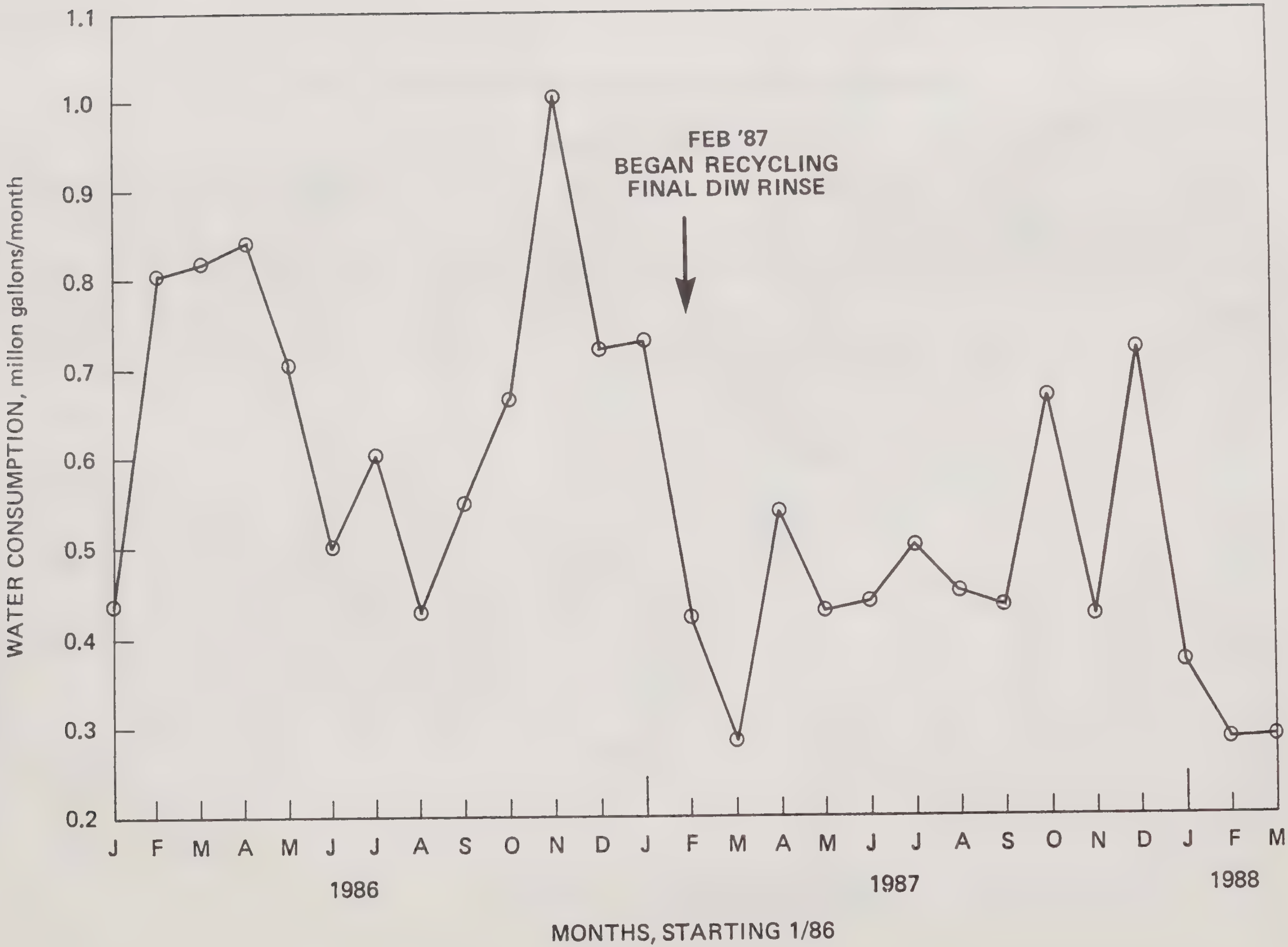


Figure 3 Water Usage at Hi—Density Effects of Water Conservation

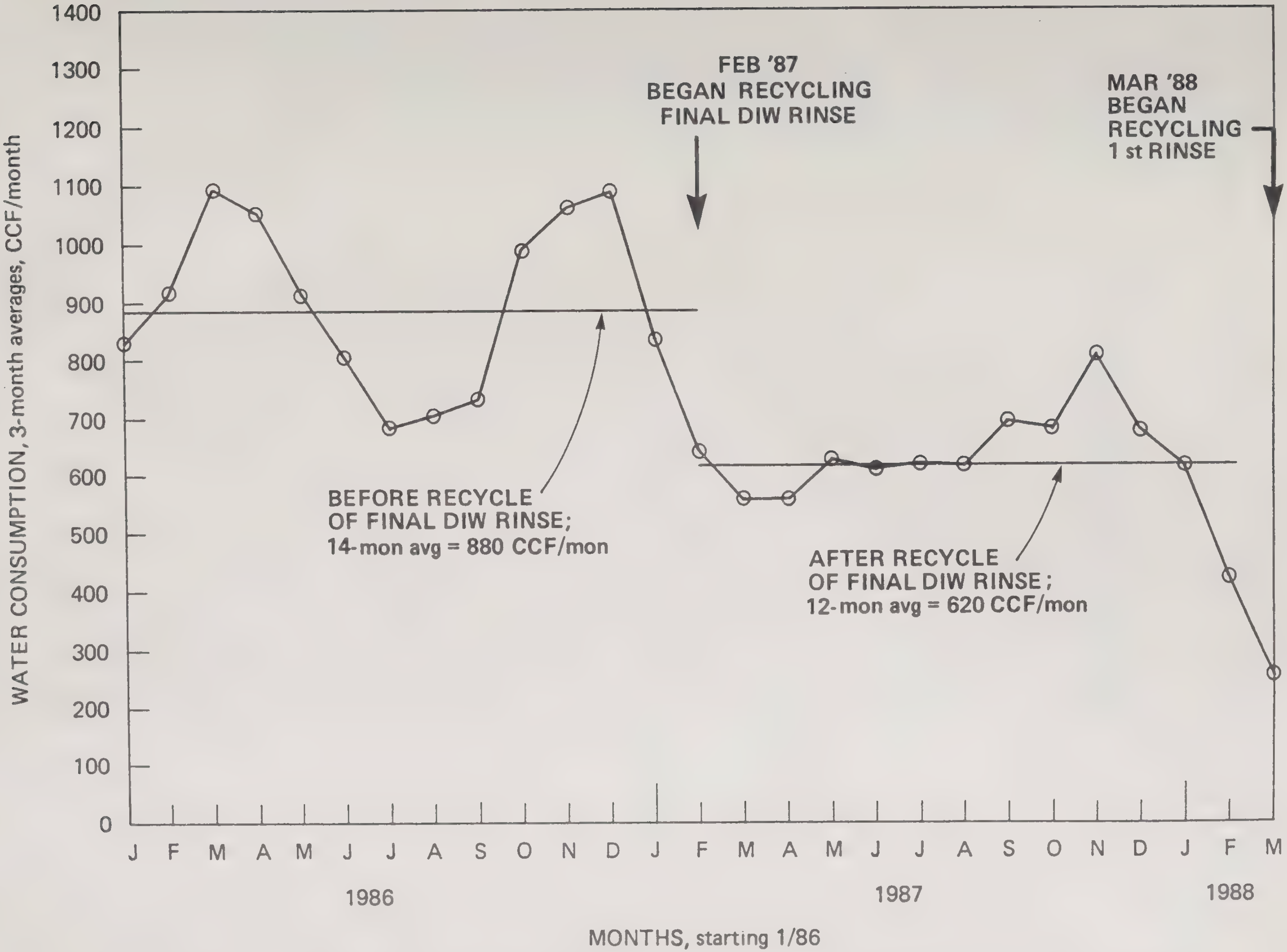


Figure 4 Water Usage at Hi–Density Effects of Water Conservation

APPENDIX D

CASE STUDY COMPANIES--PAPER REPROCESSING INDUSTRY

D.1 - California Paperboard Corporation
D.2 - Container Corporation of America

D.1

WATER CONSERVATION AT CALIFORNIA PAPERBOARD CORPORATION

Brown and Caldwell
November 6, 1989

WATER CONSERVATION AT CALIFORNIA PAPERBOARD CORPORATION

Description of Facility and Business

California Paperboard Corporation (CPC) operates a paper processing plant in an industrial area of Santa Clara, California. The plant recycles paper and cardboard into paperboard and corrugated medium at a production rate of 240 tons per day. Machine No. 1 is a cylinder machine and currently produces paperboard and machine No. 2 is a Fourdrinier machine which produces corrugated medium.

Figure 1 is a schematic of the process water flow at CPC in 1988. Water is added to the recycled fibers to create a pulp mixture, which is eventually cleaned, pressed and formed into the final product. Water is also required to cool and wash down equipment. The total amount of fresh water used in the manufacturing process is about 0.5 million gallons per day (mgd), of which 6 percent comes from city water sources and 94 percent from well water. The plant uses an average of 29,000 gallons of city water per day for toilets, sinks, drinking water, and boiler makeup water when the boiler is in operation. CPC purchases steam from a city owned cogeneration facility. The condensate is either returned to the cogeneration facility, or used when CPC's boiler is operating.

The normal operating schedule at this facility is 24 hours per day, 7 days per week, 363 days per year with 2 days down time at Christmas. There are between 100 and 125 employees on three shifts.

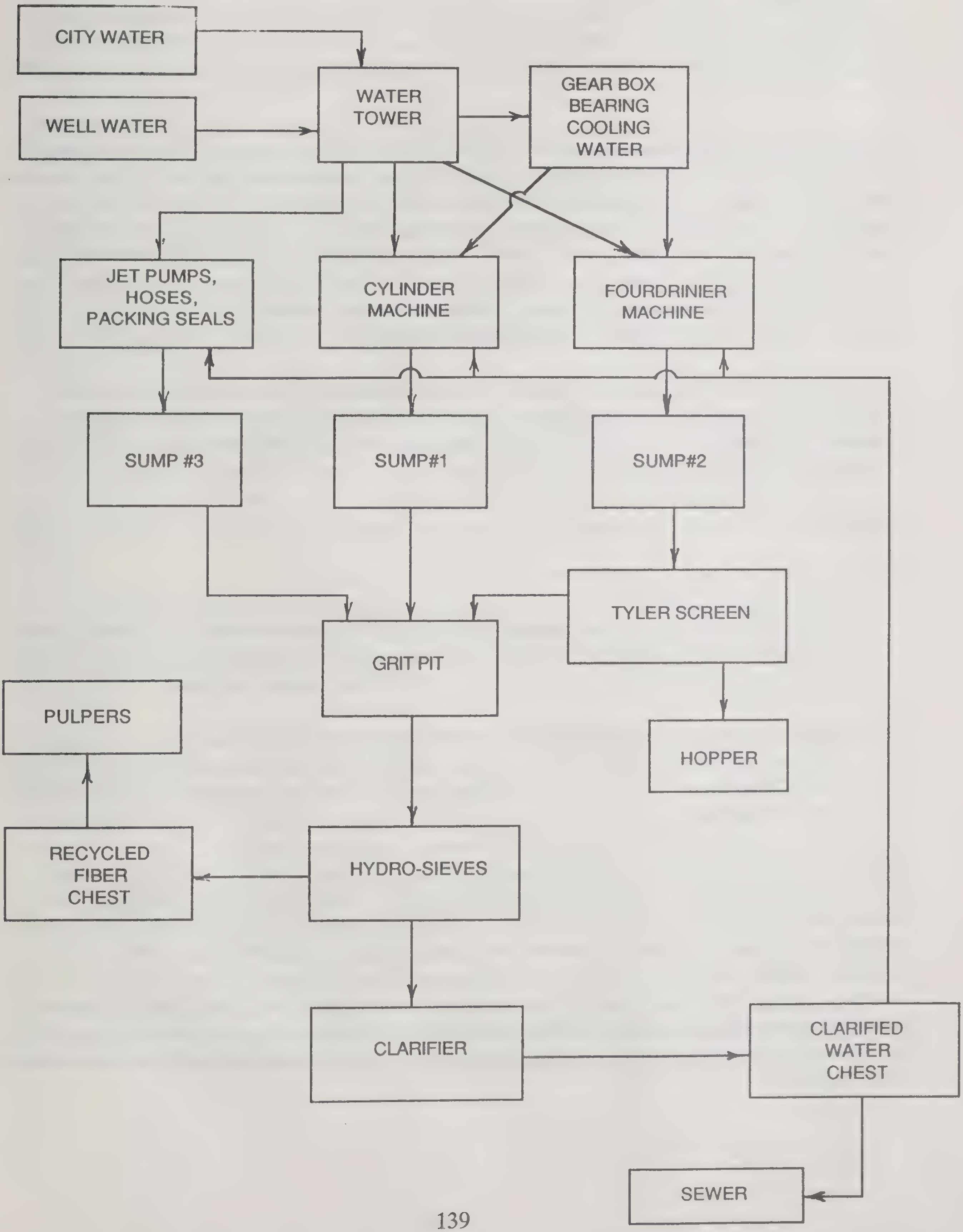
The motivation behind CPC's pursuit of water conservation was for the economic benefits involved. In addition to lower water costs, reduced water use would decrease wastewater fees and groundwater pump taxes.

Description of Conservation Actions

The major water conservation actions at CPC involve the reuse and recycling of process water. Much effort has been made to collect effluent for reuse in equipment which do not have a requirement for high quality water. These actions have been made over many years. CPC has also installed a new clarifier to recycle effluent for use in high water quality processes. The result of these water conservation measures is an overall water savings of 1.3 mgd.

As shown in the process water diagram on Figure 1, well water is pumped to an elevated water tower which is gravity fed into storage pits for use in both felt machines. The well water tower also feeds the jet pumps to provide high pressure fresh water for cooling gearbox bearings. This cooling water is collected and pumped to the high pressure felt showers on both machines. Additional well water uses include water for plant hoses and pump packing seals.

Figure 1. California Paperboard Corporation
Santa Clara Plant Water System



All process water effluent not lost to evaporation is collected in three separate basement sumps. The water is recycled through the treatment process, shown in Figure 1, to reduce BOD and suspended solids levels for reuse in various plant operations, with excess effluent discharged to the sewer. Fibers are reclaimed in the hydrosieve and are returned to the pulpers. Previously, the plant had simply discharged all effluent into the sewer.

Changes made to the recycling process in July, 1988, have increased effluent treatment efficiency. Prior to July 1988, all three effluents had to go through a Tyler screen which had a flow capacity of 150 gallons per minute. The addition of a clarifier to the treatment process allows cleaner effluent to bypass the Tyler Screen thus increasing recycle capacity. The clarifier also further reduced the BOD loading in sewer discharges and increased the fiber recycle percentage. Another benefit of the clarifier is that it provided a clearer effluent which could be reused in the cylinder showers and water seal vacuum pumps, which require a higher quality water.

CPC is planning to replace the Tyler Screen with a pea drum scalper for preliminary solids separation. The pea drum scalper would have enough capacity to handle flow from all three sumps thus making the effluent treatment process even more efficient. This upgrade should be in effect by 1990.

Results

Estimated water savings from water conservation actions are as follows.

- The entire recycle process has lowered current fresh water use to about 0.5 mgd. Without recycle, plant operations would use approximately 1.8 mgd. This results in an avoided use of 1.3 mgd, or, over 470 million gallons per year.

- The addition of the clarifier in July, 1988 is accountable for a 15-30 gallon per minute reduction in fresh water usage; equivalent to an annual savings of 8-16 million gallons. This was accomplished while increasing production of paperboard by 7 percent.

Figure 2 shows the monthly water consumption rates from May, 1987 through August, 1988 in mgd and hundred cubic feet per day (ccf/d). This plot shows a sustained low water usage at the level of about 0.5 mgd. Data are not available to show comparatively higher water usage without the recycle and reuse that is in place for this 1987 to 1988 period. Water usage during this period appears to be cyclic with greater use during the warmer summer months. This makes sense since there would be more loss of process water due to evaporation during these months. A decrease at the end of the graph is consistent with the time of the startup and the 20,000 gallons per day recycle rate of the new clarifier.

CPC's water usage rate in gallons per ton of paperboard produced, presented in Figure 3, shows the effectiveness of the clarifier in July 1988 even more dramatically. The addition of the clarifier reduced water consumption per ton by 10 to 30 percent from previous months.

Costs and Benefits

Costs associated with the process water changes at CPC are for capital and operating expenses. Capital expenses are the installed costs for all recycling equipment including pumps, sumps, piping, hydrosieves, screens and the clarifier. The total cost for this equipment is estimated to be $150,000. Amortized over a design life of 20 years at 12 percent interest, the equivalent annual cost is about $20,100.

Operating and maintenance costs for additional labor, power and equipment are approximated to be $40,000 per year. Thus, the combined capital and operating expenses for water conservation at CPC is about $60,100 per year.

An indication of the economy of water volume reduction actions at CPC can be gathered from knowledge of water supply and sewer fees, and estimates of operating costs. The cost for well water, which includes depreciation, maintenance, power, and well pump tax, is about $0.40 per thousand gallons. City water costs about $1.40 per thousand gallons. At the current ratio of well to city water use, the average cost of water is $0.46 per thousand gallons. Waste water disposal costs are approximately $1.30 per thousand gallons.

In the previous section, the water savings due to reuse and recycling is estimated to be over 470 million gallons per year. This results in an annual expense reduction of over $827,200. The cost savings due to lower water use by recycling clarified water has been an estimated $12,800 per year.

Compare these estimated annual savings with the estimated annual capital and operating costs:

$/year =	- ($/year savings due to water conservation measures) +($/year increased operating costs and amortized capital costs for additional equipment)
=	- $827,200 + $60,100
=	- $767,100 per year, savings

From the perspective of payback period for capital investment, based on the assumptions cited in this section, the simple payback period for initial capital investment is less than three months. Therefore water conservation was clearly cost effective for CPC.

Discussion

Water conservation at CPC's paperboard production plant in Santa Clara was very successful. Recycling and reuse of water produces a 72 percent lower water use than if there were no recycle, thus saving 1.3 mgd. This has saved CPC an estimated $767,100 per year in water and wastewater costs. In addition, CPC continues to improve its recycling program, with on-going modifications that will further reduce water use in 1990 and 1991.

The water conservation techniques successfully used at CPC are applicable to other paper product manufacturers as well as a wide range of other industries. Key principles of the main water conservation technique applied at CPC--recycle and reuse--are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Evaluate the degradation of water quality resulting from use in each process.
4. Evaluate whether this water can be recycled for use in the same process or other processes with little or no treatment.

Figure 2. CPC Monthly Water Usage

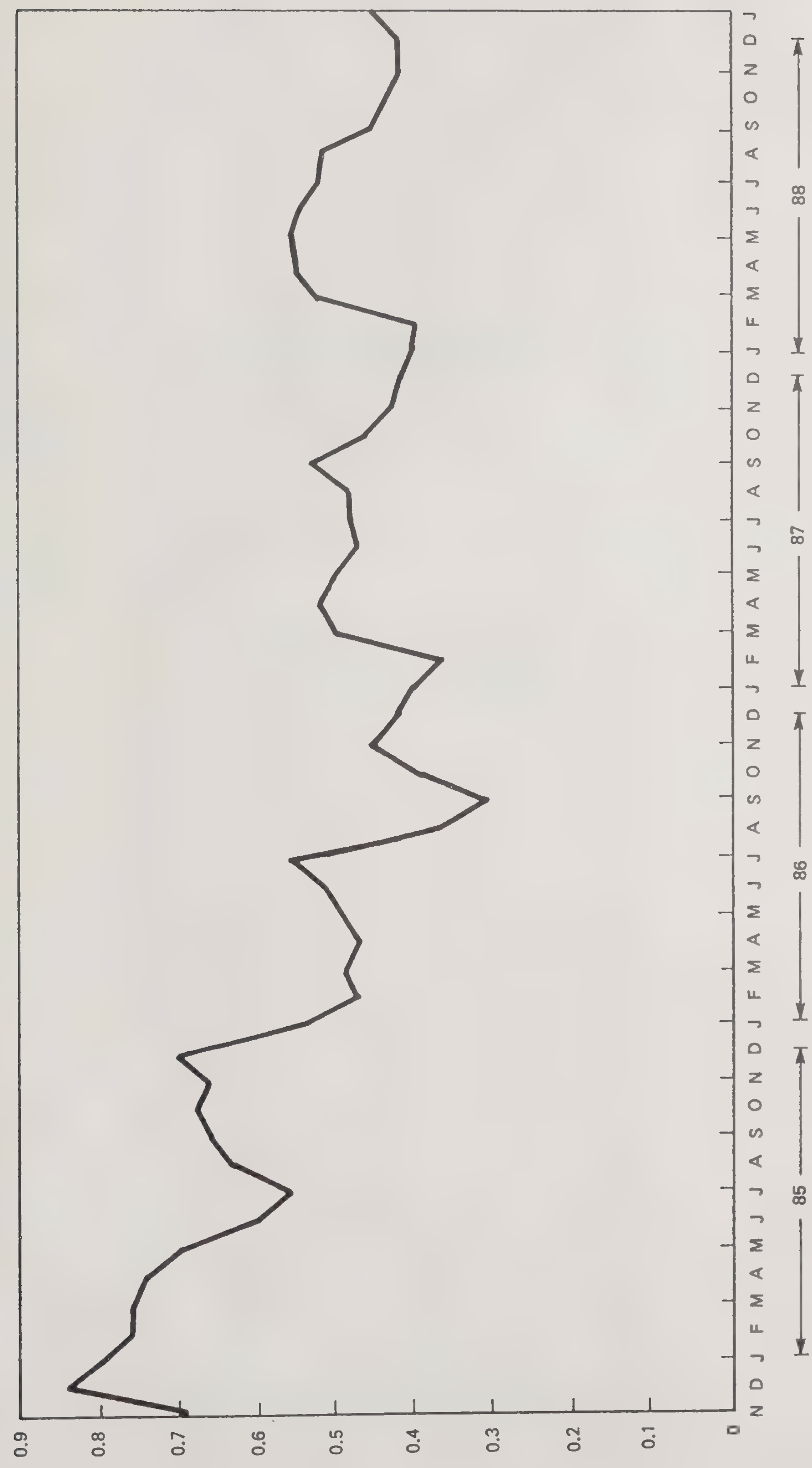
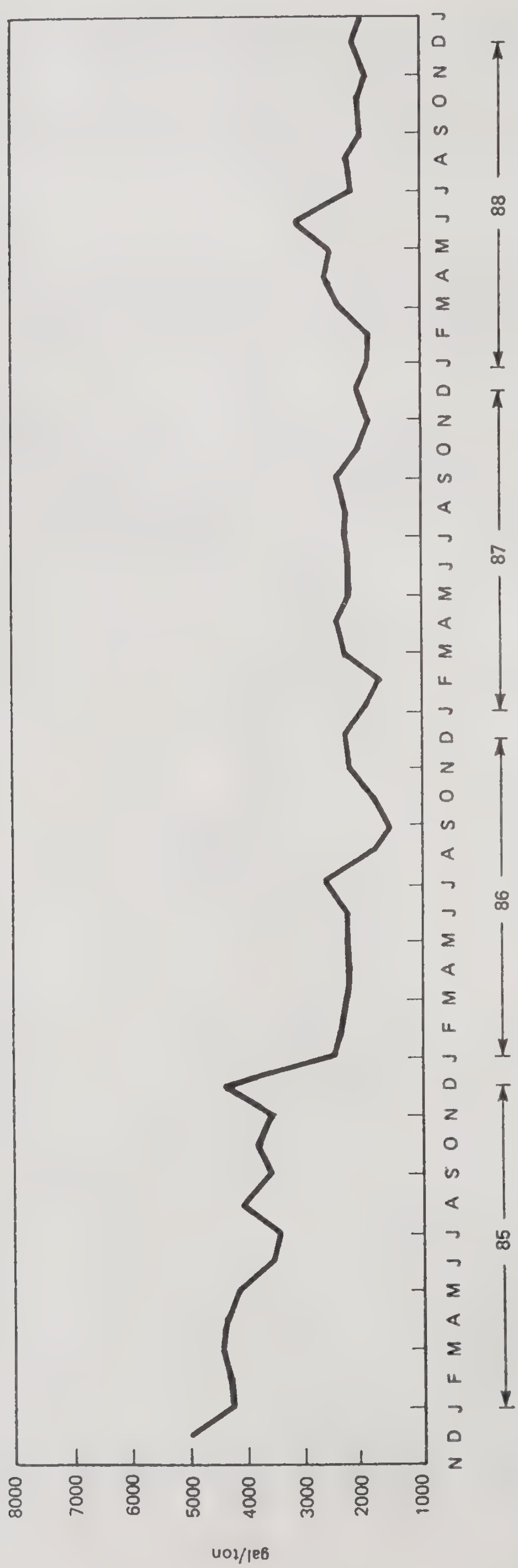


Figure 3. CPC Monthly Water Usage Gal/Ton



D.2

WATER CONSERVATION AT CONTAINER CORPORATION OF AMERICA

Brown and Caldwell
December 28, 19889

WATER CONSERVATION AT CONTAINER CORPORATION OF AMERICA

Description of Facility and Business

Container Corporation of America (CCA) operates a mill in an industrial area of Santa Clara. The mill manufactures paperboard from recycled fibers, which include newspapers, corrugated clippings, and ledger paper using an ultraformer with a production capacity of over 300 tons per day.

Figure 1 is a schematic illustration of water use at CCA's Santa Clara mill. The major use of water in the mill is in the paper machine process, where the recycled paper fibers are mixed with water to form a mixture with consistency between 2.5 and 4 percent solids. A more dilute feed improves product quality. After cleaning and refining, the pulp is formed at 1 percent consistency on the rollers and belts of the paper machine. It is then dewatered and dried to 93 percent consistency.

The single greatest amount of fresh water use in the paper machine process is in the felt needle showers, which rinse residual fibers from the belts. Additional fresh water use includes cooling water for a cogeneration facility. All process fresh water used at the mill is supplied by a groundwater well. Remaining water usage, including sanitary, drinking, and irrigation water are supplied by city tap water sources.

The normal operating schedule at this facility is 24 hours per day, 7 days per week, 353 days per year. The plant is shutdown for maintenance 10 to 12 days per year, usually around major holidays. There is a total of about 100 employees on three rotating shifts. CCA has had several studies done to develop plans for wastewater reduction and has a long history of water conservation. The motivation for CCA to pursue water conservation was for its economical benefits. Reduced water use would lower wastewater fees, water costs, water heat up costs and taxes paid on groundwater pumping.

Description of Conservation Actions

The major water conservation actions at the CCA mill were clarification and recycling of process water and the addition of a closed loop cooling tower. Several minor adjustments have been made to optimize the recycle process. Through these water conservation measures, which have taken place over several years, the mill has reduced its water use from 10,000 gallons per ton of product in 1960 to 4,000 gallons per ton in 1980, and down further to its current value of 1,600 gallons per ton.

As shown in Figure 1, fresh water from the well is used only in processes requiring high water quality and as a source of make up water. Fresh well water uses include cooling water for the cogeneration system, dilution water for clay preparation, rinsing in the trim and tail cutter, and felt needle showers. Process water is reclaimed as the pulp product is thickened and refined. Reclaimed water is collected in a water chest and is either

returned to the pulper or treated in the disc filter. The disc filter is basically a holding tank where paper fibers are added to bring the consistency up to approximately 75 pounds per 1000 gallons. The fibers provide a natural filter medium against a rotating screen to filter the water to produce three different water qualities which are maintained in separate seal tanks. High quality recycled water is very important to ensure that the savings in water use are not outweighed by increased operation costs caused by more frequent shutdowns to clean out equipment. Some of the cloudy water from the filter, along with any excess, is discharged to the sewer.

When the mill first started operation in 1957, it used a conventional cylinder machine in its paperboard process. The most significant equipment change by CCA was the replacement of the cylinder machine with an ultraformer in 1977. Not only did the ultraformer increase the production rate from 200 to 300 tons per day, but it decreased water usage due to increased recycling implemented at the same time.

The other major change to reduce fresh water usage has been the modification from a once-through freshwater plant cooling system to a closed loop cooling tower system in 1985. The cooled water, treated with a biocide and scale inhibitor, is returned to the mill and used mostly for oil coolers, brake coolers, bearing housings, a heat exchanger, and several compressors. Flow through the cooling tower is approximately 500 gallons per minute (gpm).

Recent improvements in the filter system have allowed further reduction in fresh water use. Improvements include the installation of sidehill screens. Originally intended to provide backup during annual maintenance of the disc filter, they have also been put to use during normal operations to further reduce solids in the recycle water. Several other minor operational and equipment changes have been made at the mill to reduce fresh water usage.

The addition of a Hydrofloat brand clarifier will provide water clean enough to be reused on the paper machine for felt cleaning showers, mill hoses, and dilution water. Water quality across the filter is 600 parts per million (ppm) in and less than 10 ppm out, or 99 percent reduction in solids. This will reduce fresh water intake another 150 to 250 gpm.

<u>Results</u>

Estimated water savings from water conservation actions are as follows.

- Overall water conservation measures have cut fresh water use from about 4,000 gallons per ton in 1980 to about 1,600 gallons per ton currently. (Reductions are even more dramatic when compared with 1960 use rates.) For the present production of 300 tons of paper products per day, CCA uses about 480,000 gallons (640 hundred cubic feet [ccf]) per day. This is 720,000 gallons (960 ccf) per day less than would have been used at the 1980 rate. Recent conservation measures thus account for savings of 250 million gallons (340,000 ccf) per year.

- Replacement of the cylinder machine with the ultraformer in 1977 cut fresh water use in this process by 50 percent while increasing production by 33 percent.

- The addition of the cooling tower in 1985 accounts for a 50 to 100 gpm reduction in water usage; equivalent to an annual savings of 50 million gallons.

Figure 2 shows water consumption at CCA in million gallons per day (mgd) and ccf/d over three separate time periods. In its first four years of operation the CCA mill used over 1,400,000 gallons per day with this rate increasing as production increased. After installation of the disc filter and initial recycle loops in the early 1960's and the replacement of the cylinder machine with the ultraformer in 1977, the water usage rate dropped dramatically to about 1,000,000 gallons per day.

The water savings are actually better reflected when the data is presented in gallons per ton of paperboard produced as shown in Figure 3. Between 1960 and 1980, the water usage rate was lowered from about 10,000 gallons per ton to about 4,000 gallons per ton. From 1978 through 1983 there is a continuing trend of reduction in both normalized and overall water use. This was achieved through continuing efforts of improving the filtering and recycle systems.

The final time frame shown in Figures 2 and 3 indicate current 1988 water usage rates. These rates reflect the water savings due to the installation of the cooling tower recycle system, which was the only major change since 1984. Average water savings attributable to this action total 300,000 gallons per day, or 100 million gallons per year.

Costs and Benefits

Costs associated with the process water changes at CCA are for capital and operating expenses. However, the installation of the ultraformer, which created significant water savings, was planned for increased productivity rather than water conservation and therefore will not be included in the capital costs. Equipment installed solely for water conservation include the cooling tower, the disc filter, various tanks, piping, and pumps. The total capital cost for this equipment in current dollars is estimated to be $200,000. Amortized over a design life of 20 years at 12 percent interest rate, the equivalent annual cost is about $26,800.

Additional operating and maintenance costs for equipment are approximated to be $50,000 per year. This includes cost for labor, power, and replacement parts. Thus, the combined capital and operating costs for water conservation at CCA is about $76,800 per year.

An indication of the economy of water volume reduction actions at CCA can be gathered from knowledge of water supply and sewer fees, and estimates of operating costs. The cost for well water, which includes depreciation, maintenance, power, and well pump tax, is about $0.40 per thousand gallons. Waste water disposal costs are approximately $1.30 per thousand gallons.

Comparing the current water use rate to that of 1980, there is a savings of approximately 250 million gallons per year. This results in a reduction of $425,000 in annual water costs. This was achieved while increasing production by 33 percent.

Compare these estimated annual savings with the estimated annual capital and operating costs. Based on savings relative to 1980 water use rates, there is a substantial economical benefit from water conservation:

$/year = - ($/year savings due to water conservation measures)
+($/year increased operating costs and amortized capital costs for additional equipment)

= - $425,000 + $76,800
= - $348,200 per year, savings

From the perspective of payback period for capital investment, based on the assumptions cited in this section, the simple payback period for initial capital investment is about 7 months.

The current Hydrofloat capital project is $230,000. This includes pumps, piping, and a sludge compressor.

Discussion

Water conservation at CCA's Santa Clara mill was very successful. In the 21 years since start up, overall water use has been reduced over 60 percent. In that same time, the production rate has increased over 33 percent, so that water use based on production was reduced 86 percent.

The water conservation techniques successfully used at CCA are applicable to other paper product manufacturers as well as a wide range of other industries. Key principles of each water conservation technique applied at CCA are analyzed below.

Recycling water must be done within limits of required water quality. Elements of this in-process recycling water conservation technique are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Evaluate the degradation of water quality resulting from use in each process.
4. Evaluate whether this water can be recycled for use in the same process or other processes with little or no treatment.

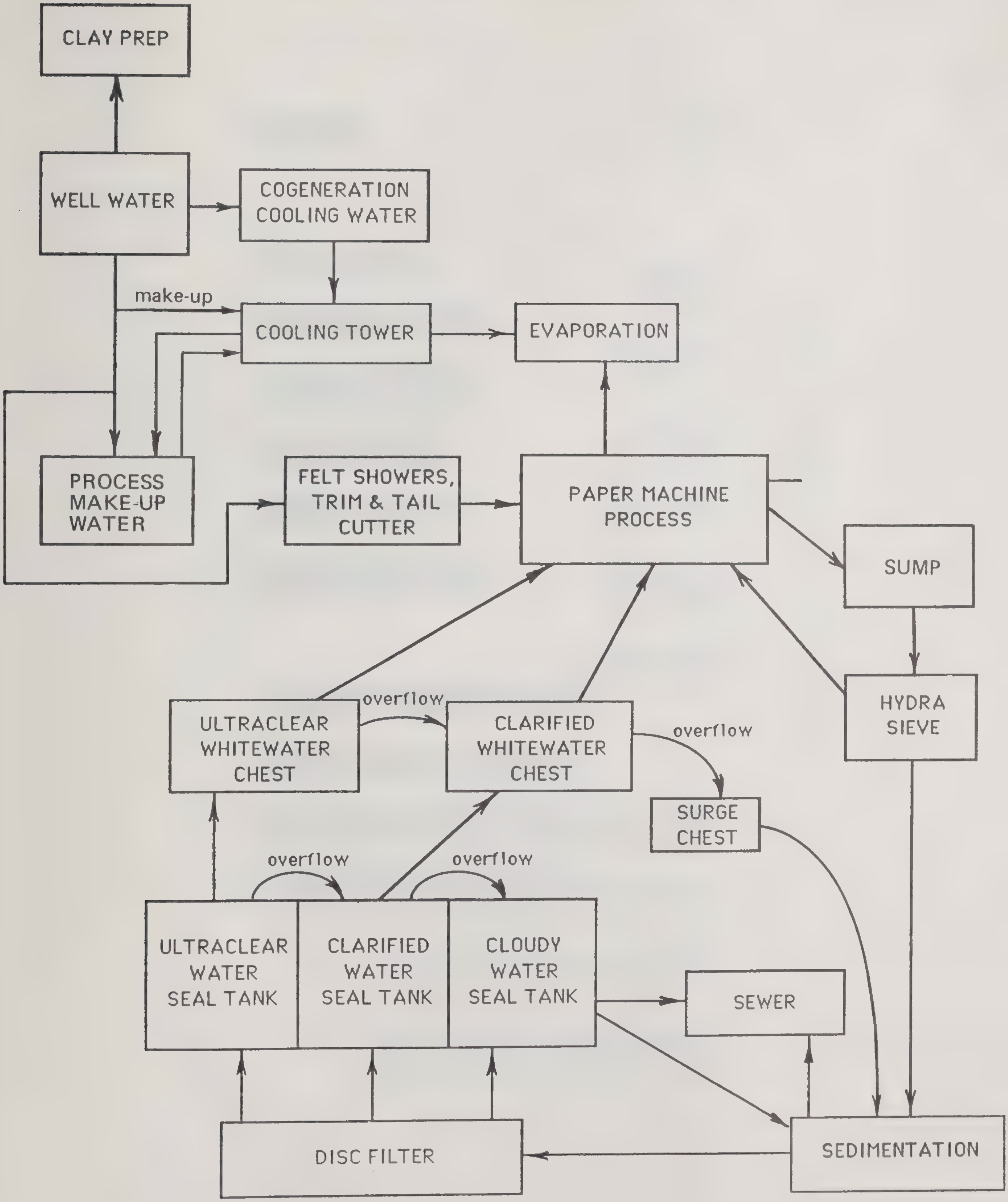
The second category of water conservation technique presented in this case study was cooling towers. Elements of this technique are:

1. Identify cooling requirements currently using once-through water for cooling.
2. Evaluate cooling requirements and how a cooling tower might meet them.

The third category was equipment modification. Elements of this technique are:

1. Identify major water uses.
2. Evaluate and retrofit to use the minimum quantity of water needed for this application.

Figure 1. CCA Santa Clara Mill Water System



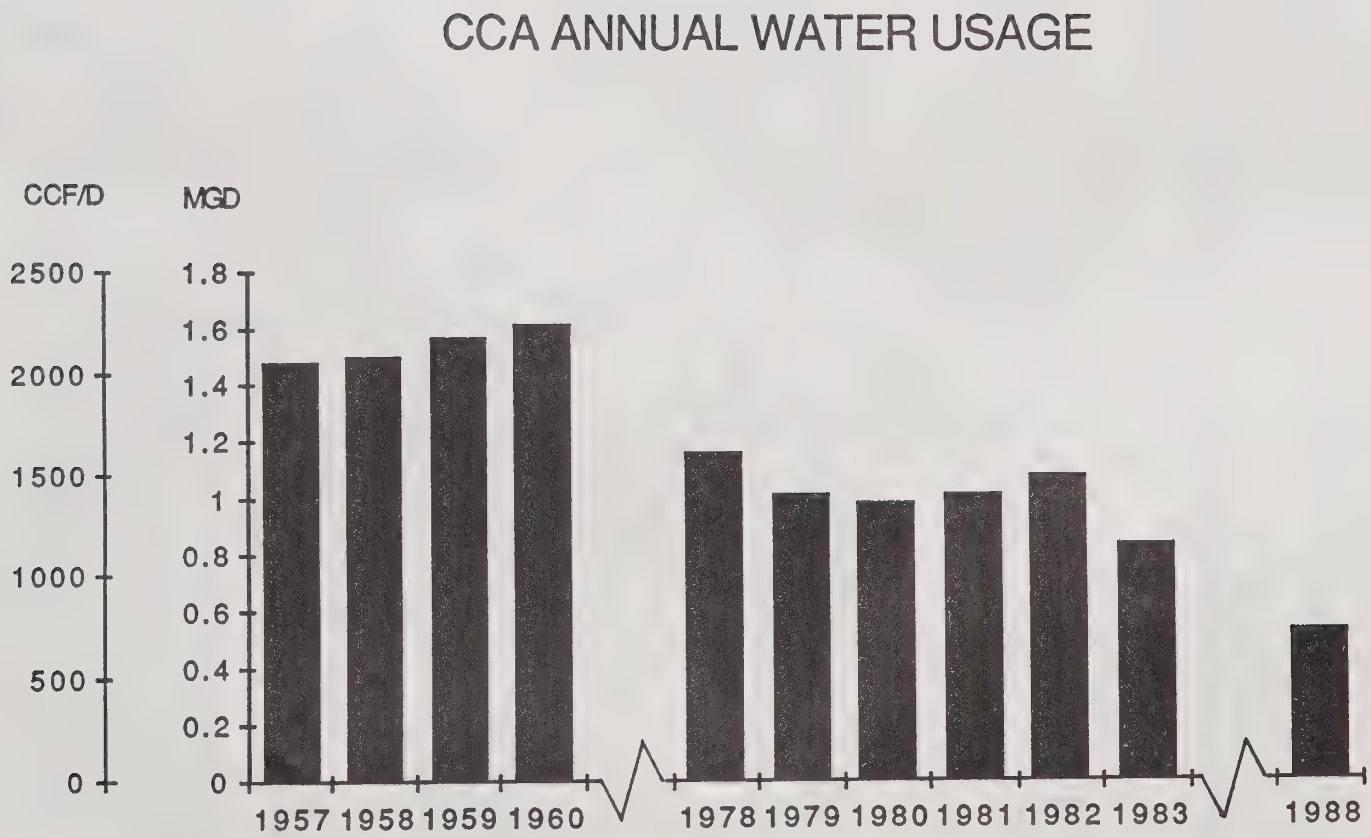


Figure 2. CCA Annual Water Usage

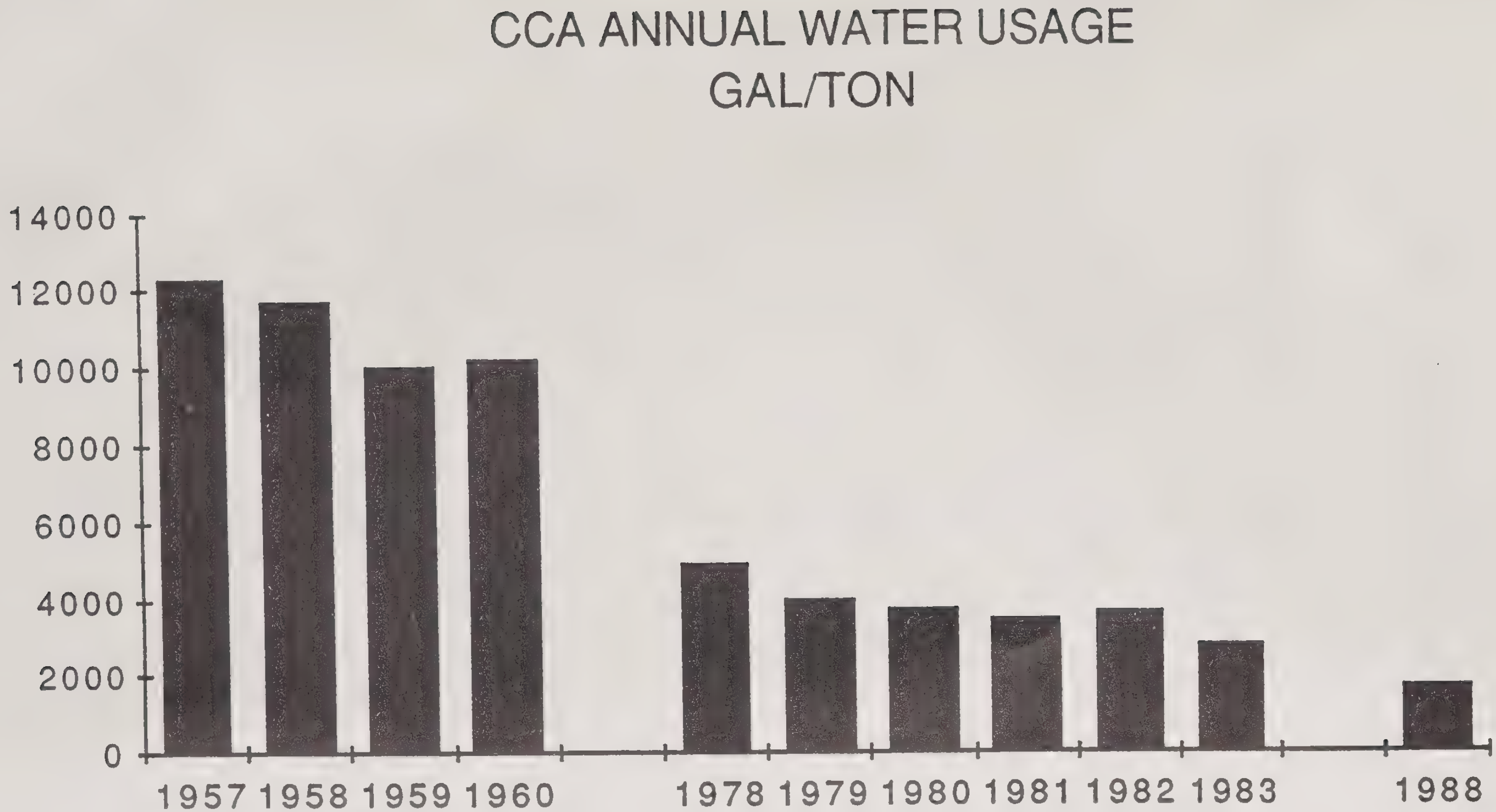


Figure 3. CCA Annual Water Usage Gal/Ton

APPENDIX E

CASE STUDY COMPANIES--FOOD PROCESSING INDUSTRY

Gangi Bros. Packing Company

E.

WATER CONSERVATION AT GANGI BROS. PACKING COMPANY

Brown and Caldwell
January 3, 1990

WATER CONSERVATION AT GANGI BROS. PACKING COMPANY

Description of Facility and Business

Gangi Bros. Packing Company is a tomato processing and canning plant located in an industrial area of Santa Clara. Major uses of water in processing and canning at Gangi Bros. are:

1. Fluming tomatoes from trucks.
2. Tomato rinsing.
3. Vacuum pump seals.
4. Boiler makeup.
5. Cooling.

Figure 1 is a schematic illustration of water use at the Gangi Bros. cannery. The cannery obtains water mainly from one of its three on-site wells and also from the public water supply. Well water is used for canning process water needs. Tap water is used for boiler makeup, drinking water, and rest rooms.

The normal operating schedule at this facility is 24 hours per day, 7 days per week, during the canning season from July to October. There is an average of about 150 employees on each shift.

The motivation for Gangi Bros. plant staff to pursue water conservation was a general concern for efficiency.

Description of Conservation Actions

The canning industry uses large quantities of water and has historically used some recycling and reuse of water[1]. Water conserving process changes at Gangi Bros. have been implemented over many years. Techniques successfully used at this cannery fall into the following categories:

1. Recycling of water within one process.
2. Reuse of water in another process.
3. Cooling tower loops.
4. Modifying processes to use less water.
5. Monitoring operations to control water use.

Recycling and Reuse. Two major conservation techniques at Gangi Bros. have been water recycling within one processing step and reusing water in other steps. Since steps of the canning process are integrated, there is not always a clear distinction between recycling and reuse. Recycling water is done within a process and may require some sort of treatment to control the water quality so that it

remains satisfactory for that use. In contrast, reusing water in a different process usually does not require any treatment, since the subsequent applications are often ones which have lower water quality requirements.

Gangi Bros. has adapted recycling measures in the fluming operation, where water conveys tomatoes from delivery trucks to processing lines. After the trucks unload large bins of tomatoes (about 350 cubic feet) onto cannery platforms, water is discharged into the bins to carry the tomatoes through an opened bin gate into channels which lead to tomato sorting equipment. The water from the lower flumes is recycled to the bin discharge valves. Also, water is recycled around the side dump flume system.

Reuses at the Gangi Bros. cannery takes the form of an overall cascading of water through several processes. Fresh water is used in the processes requiring clean water or in processes which do not lower its quality. Major uses requiring clean fresh water are water to the vacuum peelers and pumps, makeup to the cooling towers and boiler, drinking water, and rest rooms (office use). On Figure 1, these are shown receiving water supply. Major uses which do not degrade the water quality are water seals on the vacuum pumps and barometer legs of the vacuum peelers; some water is recovered and reused from both of these uses. Secondary reuses of water at the Gangi Bros. cannery are fluming and rinsing of tomatoes. For sanitation, chlorine is applied to reuse streams.

Cooling Tower Loops. Cooling towers are systems for treating water to enable recycle in applications where the use of water is for cooling. Examples of these applications are condensers, compressors, or product coolers. The "treatment" of the water is removing the heat from the cooling water by evaporation.

Cooling towers are common in canneries, since there is much use of heat, and consequently need to cool water, steam, or product. However, cooling towers have historically not been applied at every opportunity in canneries, due to past abundance of low cost water[1]. At Gangi Bros., an effort has been made to use cooling towers for all major cooling water streams.

Two large cooling towers are used for cooling the evaporators' condensers. Flow in these two cooling towers is 3,600 gallons per minute (gpm). Blowdown from these towers, which removes salts that build up as water evaporates, is about 57 gpm. Fresh makeup water comes from the evaporators' second effect condensate and liquid ring vacuum pumps via the hot well. It is automatically controlled to maintain a set level of water in the cooling towers. The flow rate of makeup water is about 120 gpm. This flow is the sum of that periodically discharged as blowdown plus that lost through evaporation and drift (droplets carried off in the air). Evaporation and drift vary greatly with the weather and cooling load. The average water quantity lost to evaporation and drift at Gangi Bros. is in the range of 40 to 60 gpm.

Another cooling tower at the Gangi Bros. cannery is used for recycling 500 gpm of water in two-can cooling machines. This cooling tower also has automatic makeup. There is, however, no need for blowdown. Small amounts of water are dragged out on the cans. Along with this water goes small amounts of dissolved salts, enough to keep salts from building up in the circulating water.

Modifications of Equipment. Three notable equipment modifications have been made for water conservation at the Gangi Bros. cannery. The first is the installation of special timed gate valves on the tomato bulk dump systems that provide short duration high volume flows to control mud and water flush cycles. The source of this water is recycled flume water.

The second is the use of high-pressure, low-volume rinse water for plant sanitation and belt cleaning. The high-pressure system uses Kobe equipment and operates at 800 to 1,100 psi. This system replaced water rinsing done at normal water delivery pressure of 50 to 80 psi. This change was made in 1985. This water is fresh water, so the savings accumulate directly.

The third equipment modification was flow restrictors on vacuum pumps. On the two peelers that are in use at the Gangi Bros. cannery, flow restrictors have been installed on the water suction lines of the vacuum pumps. A third pump at the evaporator also has a flow restrictor. The first of these restrictors was installed 5 weeks into the 1987 season, approximately the beginning of August 1987. The second and third were installed at the beginning of the 1988 canning season. The flow restrictors reduced well water used from 49 to 13 gpm on each pump.

Employee Education. In addition to the process design changes described above, Gangi Bros. has applied a strong employee training and monitoring program. Employees have been instructed that water conservation is company policy. Supervisors watch for water waste, such as unattended running hoses.

Results

Water conservation at this cannery has been very successful. Figure 2 shows water consumption at Gangi Bros. has significantly decreased over the last 5 years. This figure shows water and in acre-feet per year. In the 1983 canning season, Gangi Bros. used about 200,000 ccf (455 acre-feet). By the 1989 season, conservation measures dropped water use to about 75,000 ccf (174 acre-feet), a savings of 125,000 ccf (281 acre-feet) per season. This seasonal use is concentrated into a 4-month canning period.

In actuality, water conservation was more successful than the reduction in water volume shown on Figure 2. Industrial water use is most appropriately expressed in terms of water use per unit of product. Gangi Bros. cannery has increased its operating volume during the same period during which they reduced water consumption. Figure 3 shows the ratio of water use to net tons of tomatoes processed. This shows how water conservation was even more successful than indicated by consumption alone. Water

usage per production is even better when stated as gross (received) tonnage, which is 4 to 5 percent more than net tonnage.

Water use at other canneries appears to be higher than at Gangi Bros. For comparison, water use per ton of tomatoes processed for two tomato canneries in the San Jose area are listed in Table 1. These other two canneries lowered water usage from 1973 to 1976 by combinations of measures similar to those used at Gangi Bros. These were employee awareness programs, addition of cooling towers, mechanical peelers, high-pressure cleaning flows, cutback of flows to some equipment, and recycling flume water after separation of mud. The further reduction of water usage by Gangi Bros. suggests potential for even greater water conservation at canneries.

Table 1. Tomato Cannery Water Usage

	Gallons/ton processed (year)			
Cannery	1973	1976	1983	1988
A	2,000	1,300	-	-
B	2,700	1,400	-	-
Gangi Bros.	-	-	1,200	300

Costs

To give an idea of the cost-effectiveness of the water conservation techniques employed at the Gangi Bros. cannery, an analysis of the direct associated costs and savings follows. There are significant indirect effects, both economic and noneconomic. Examples of these are avoidance of water supply limitations obstructing future business expansion and improved community relations. Indirect effects have not been included in the following analysis.

The costs related directly to water conservation at this cannery are those for new equipment and added maintenance labor. Direct cost savings are for reduced water supply and lowered wastewater disposal costs. The costs can be approximated from water supply and sewer fees and estimates of other costs.

Savings From Reduced Water Volume. Combined costs of water and sewer service are essentially variable in proportion to water volume. Most of the water used at this cannery is pumped from one of 3 on-site private wells. The estimated cost of this well water, including depreciation, maintenance, power, and taxes, is about \$0.42 per thousand gallons[2]. Additionally, 75 percent of net water use at the cannery is assumed to be disposed of to the sewer, and the cost of wastewater disposal is assumed to be \$1.30 per thousand gallons. Although city water is used

for boiler makeup, drinking, and rest rooms, identified water conservation at the Gangi Bros. cannery has been in process applications using well water. Therefore, savings are calculated from the costs of supplying well water.

Costs of Water Conservation Actions. The costs of water conservation at this cannery are estimated form costs of similar major equipment and assumptions about added operating expenses due to water conservation actions. For instance, the costs for using cooling towers are for original equipment purchase, and operating expenses are for maintenance and water treatment chemicals.

Estimated additional operating and maintenance costs are for:

a) power for fans and pumps, $20,000 per year.
b) chemicals and materials, $5,000 per year.
c) added labor, $5,000 per year.

Capital costs are for:

a) 2 cooling towers for evaporators.
b) 1 cooling tower for can cooler.
c) 3 flow restrictors on existing pumps.
d) 4 recycle pumps.
e) 16 timed valves.

The capital cost estimate for the two large cooling towers, at current prices, including installation, is about $20,000 each. The smaller can cooling tower would cost about $15,000 today. Flow restrictors have negligible capital cost. The four recycle pumps are estimated to have a total capital cost: of $20,000, and the special gate valves, $2,000.

Total capital cost is estimated to be $77,000. Amortized over a design life of 20 years at 12 percent interest rate, the equivalent annual cost is about $10,500.

Combined estimated capital and operating costs for the water conservation in place at the Gangi Bros. cannery is about $40,500 per year.

Comparison of Costs With Savings. Estimated net water savings, for the individual water conservation actions at Gangi Bros. cannery are about 125,000 ccf per year, the reduction in water use from 1983 to 1989.

At a combined cost of water supply and wastewater disposal equal to $1.40 per thousand gallons, based on well water cost of $0.42 per thousand gallons, wastewater disposal cost of $1.30 per thousand gallons, and wastewater to intake ratio of 75 percent, the savings is about $130,000 per year.

Compared with the estimated annual cost for equipment and operation, the savings due to lower water and sewer costs are considerable:

\$/yr.	=	- (\$130,000/yr lower water and sewer costs)
		+(\$ 10,500/yr amortized capital costs)
		+(\$ 30,000/yr added operating costs)
	=	- \$ 89,500/yr, net savings

From the perspective of payback period for capital investment, based on the assumptions cited in this section, the simple payback period for initial capital investment is about 10 months.

<u>Discussion</u>

Water conservation at the Gangi Bros. cannery in Santa Clara was very successful. In six years, total water usage was cut by nearly two-thirds. The effectiveness of water conservation was even better than this figure indicates. This was a period of increased production at the cannery. Water usage relative to processed quantity of tomatoes was cut by three-quarters.

Transferability of the water conservation techniques used by the Gangi Bros. cannery is high. These methods are applicable both to other canneries and to a wide range of industries. Key principles of each water conservation technique applied at Gangi Bros. are analyzed below.

Reusing and recycling water must be done within limits of required water quality. Elements of this in-process recycling water conservation technique are:

1. Identify major water uses.
2. Evaluate the minimum water quality needed for these uses.
3. Evaluate the degradation of water quality resulting from use in each process.
4. Evaluate whether this water can be recycled for use in the same process with little or no treatment or reused in another process.

The second category of water conservation technique presented in this case study was cooling towers. Elements of this technique are:

1. Identify cooling requirements currently using once-through water for cooling;
2. Evaluate cooling requirements and how a cooling tower might meet them.
3. A further element in changing cooling systems for water conservation, not used in this case, is consideration of nonevaporative cooling loop systems.

The third category was equipment modification. Elements of this technique are:

1. Identify major water uses.
2. Evaluate and retrofit to use the minimum quantity of water needed for this application.

A fourth category, monitoring operations, has the elements:

1. Establish what are reasonable water use practices.
2. Notify employees of these proper practices.
3. Monitor and enforce proper water use practices.

<u>References</u>

1. Doucett, Walt, "Water Conservation at a Large Cannery," in Proceedings of the Conference on Water Availability and Conservation, April 28, 1977, Oakland, Allen Katsuyama, ed., National Canners Association and Canners League of California.

2. Katsuyama, Allen, "Immediate Water-Saving Measures, "in Proceedings of the Conference on Water Availability and Conservation, April 28, 1977, Oakland, National Canners Association and Canners League of California.

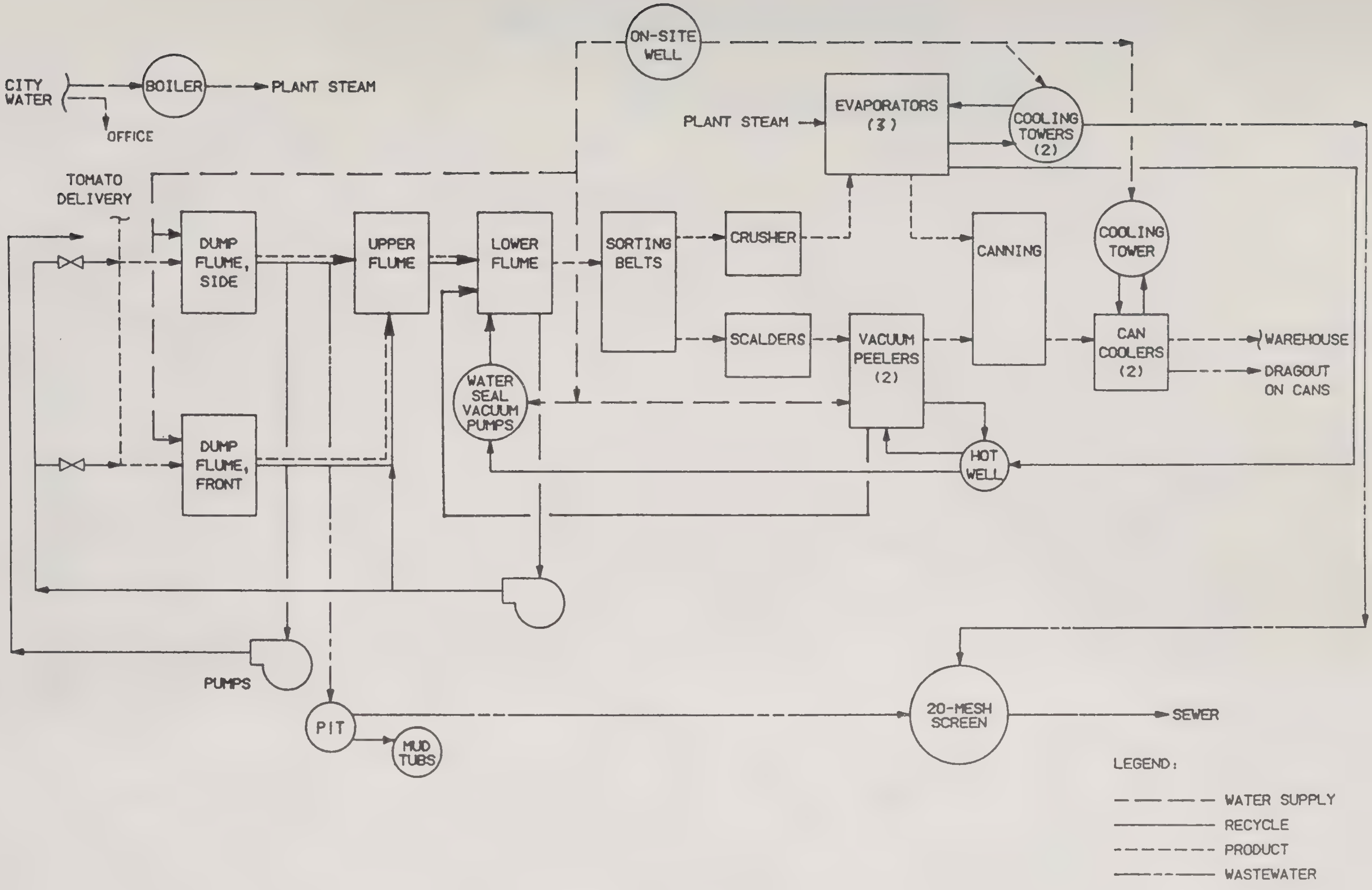


Figure 1 Water Usage at Gangi Bros. Cannery

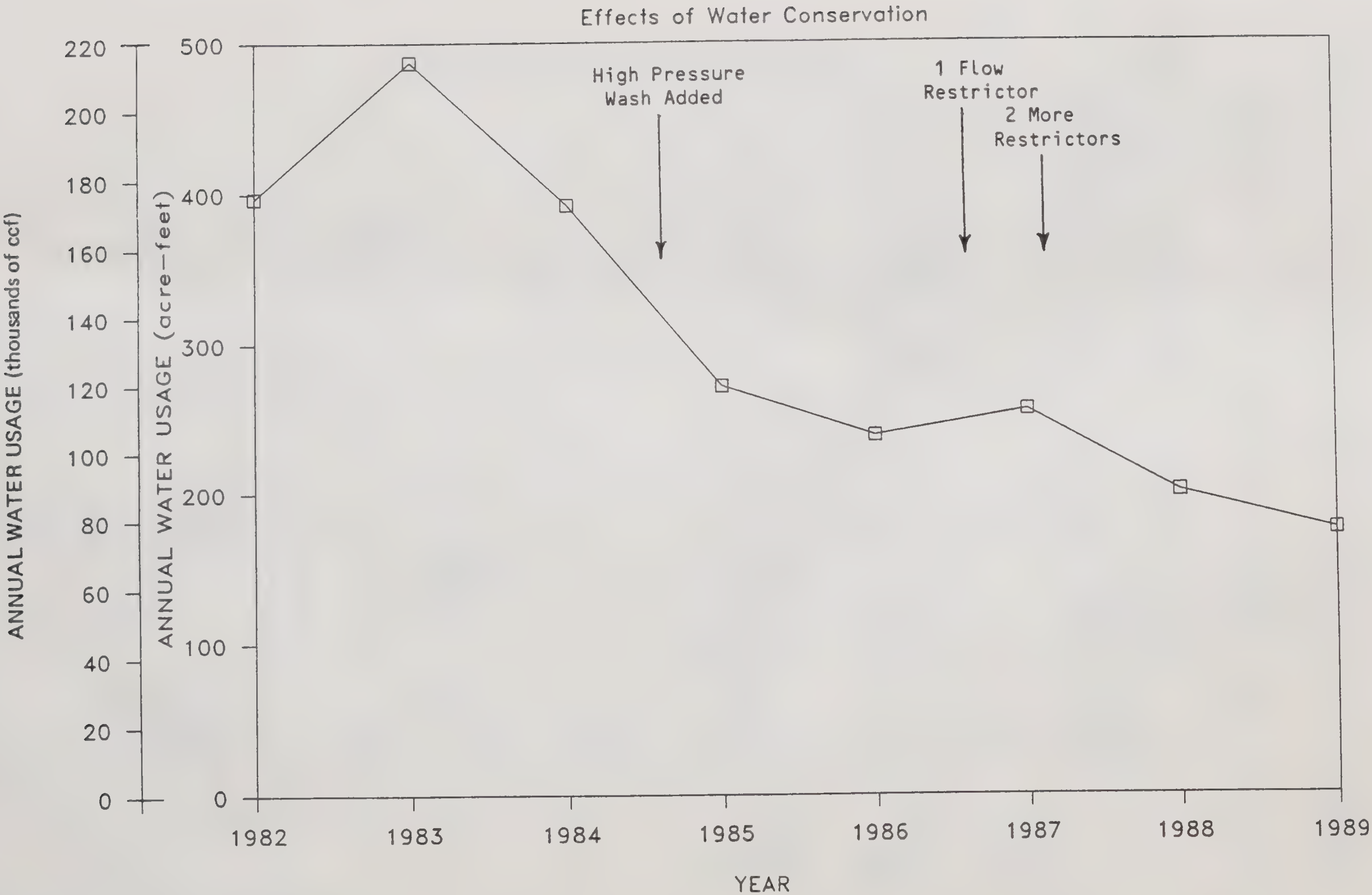


Figure 2 Water Usage at Gangi Bros. Cannery

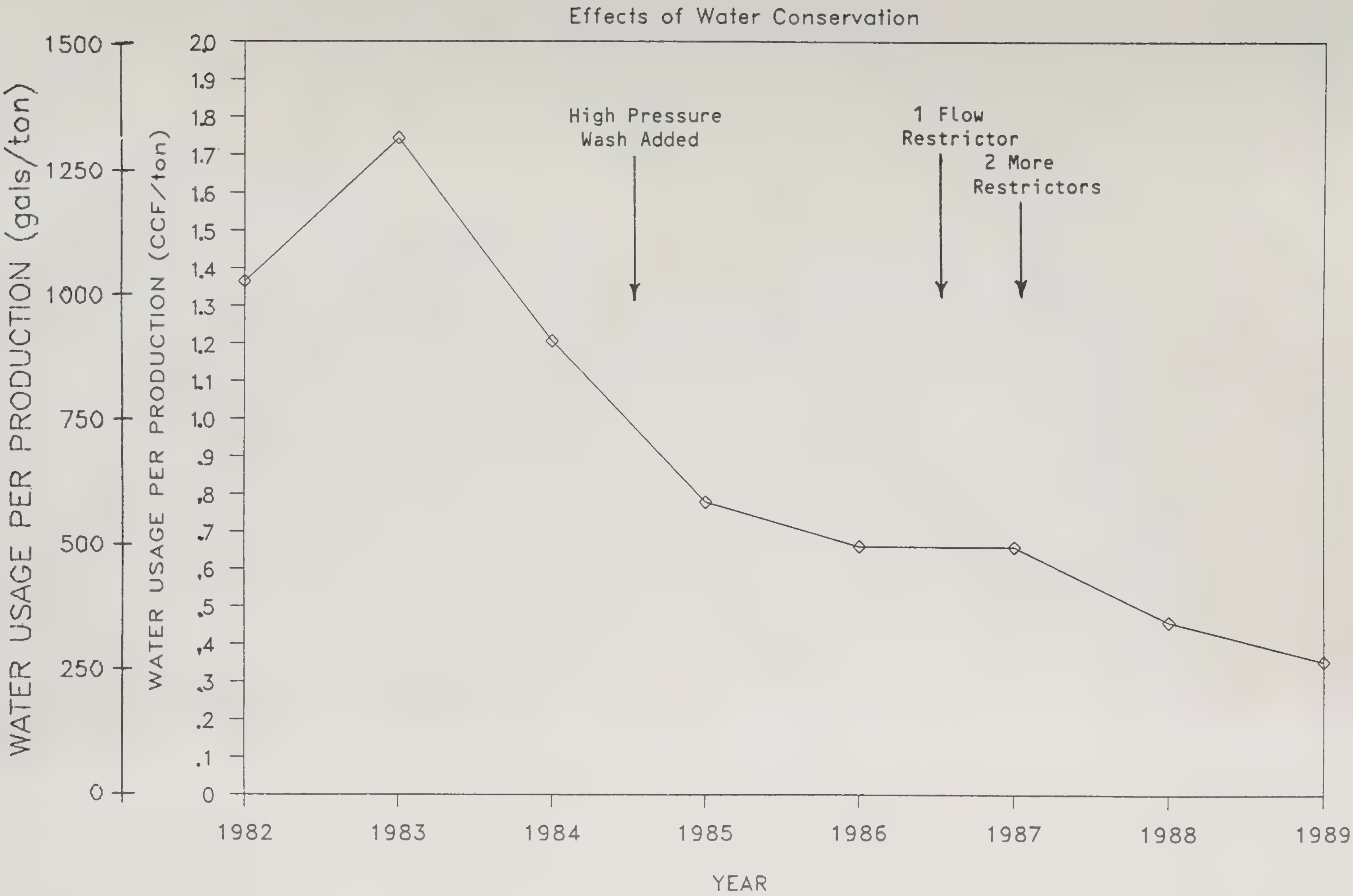


Figure 3 Water Usage per Production

State of California--The Resources Agency
Department of Water Resources
P.O. Box 942836
Sacramento, CA 94236-0001